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BULLETIN
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Massachusetts Institute of Technology

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PRESIDENT'S OFF

DEPARTMENT
OF
MECHANICAL ENGINEERING

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OF THE
Massachusetts Institute of Technology
BOSTON

UNIVERSITY OF ILLINOIS

PRESIDENT'S OFFICE

1861

DEPARTMENT
OF
MECHANICAL ENGINEERING

FEBRUARY, 1909

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SCHEDULE OF THE COURSE IN MECHANICAL ENGINEERING.

FIRST YEAR.

FIRST TERM.

Mathematics (Algebra).
Trigonometry.
Inorganic Chemistry.
Chemical Laboratory.
Descriptive Geometry and Mechanical Drawing.
Freehand Drawing.
Rhetoric and English Composition.
German or French.[1]
Military Science.
Physical Training.

SECOND TERM.

Mathematics (Algebra, Analytic Geometry, Elements of Calculus).
Inorganic Chemistry, Qualitative Analysis.
Chemical Laboratory.
Descriptive Geometry and Mechanical Drawing.
Freehand Drawing.
Rhetoric and English Composition.
United States History.
German or French.[1]
Military Science.
Physical Training.

SECOND YEAR.

FIRST TERM.

Carpentry and Wood Turning.
Descriptive Geometry.
English Literature.
European History.
Mathematics (Analytic Geometry, Calculus).
Mechanical Engineering Drawing.
Mechanism.
Physics (Mechanics, Electricity, Optics).

SECOND TERM.

Applied Mechanics.
English Literature.
Mathematics (Calculus, Differential Equations).
Mechanical Engineering Drawing.
Mechanism and Valve Gears.
Pattern Work.
Physical Laboratory.
Physics (Electricity, Optics).
Precision of Measurements.

THIRD YEAR.

FIRST TERM.

Applied Mechanics.
Mathematics.
Forging.
General Studies.
Machine Drawing.
Metallurgy of Iron.
Physical Laboratory.
Physics (Heat).
Political Economy.
Steam Engineering: Thermodynamics.

SECOND TERM.

Applied Mechanics.
Applied Mechanics Laboratory.
Business Law.
Electrical Engineering.
Engineering Laboratory.
Forging: Chipping and Filing.
General Studies.
Heating and Ventilation.
Mechanical Engineering Drawing; Boiler Drawing.
Steam Engineering: Boilers.
Use of Surveying Instruments.

FOURTH YEAR.

FIRST TERM.

Applied Mechanics.
Dynamics of Machines.
Electrical Engineering.
Electrical Engineering Laboratory.
Engineering Laboratory.
Foundry.
Machine Design.
Machine-tool Work.
Theoretical Hydraulics.

Options.

1. Marine Engineering.
2. Locomotive Construction.
3. Mill Engineering.
4. Heating and Ventilating Engineering.
   Hygiene of Ventilation and Heating.
5. Steam Turbine Engineering.

SECOND TERM.

Engineering Laboratory.
Foundations.
Hydraulic Motors.
Industrial Management.
Machine Design.
Machine-tool Work.
Power Plants.
Thesis.

Options.

1. Marine Engineering.
2. Locomotive Engineering.
3. Mill Engineering.
4. Heating and Ventilating Engineering.
5. Steam Turbine Engineering.

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[1] German advised.

THE COURSE IN MECHANICAL ENGINEERING.

DESCRIPTION OF THE COURSE.

The Course in Mechanical Engineering, which is one of those established at the foundation of the Institute, aims to give to the student a thorough training in the scientific principles that form the basis of all Engineering, and to do this in such a manner that the student may be able, instead of relying upon rule-of-thumb methods, to apply these principles to the solution of the practical problems that will arise after he leaves the school and enters active life. It aims not only to acquaint him with current engineering practice, but also to develop the powers of his mind so that he may be able to make improvements, as occasion may arise, and thus keep abreast of the times. As large a practical element as time will allow is introduced into the recitation-room, the drawing-room, and the laboratory, the practical work being arranged to follow, and not to precede, the theoretical instruction bearing upon it.

The instruction includes courses in such fundamental subjects as Mechanism and Valve-gears, Applied Mechanics, Thermodynamics and Steam Engineering, together with the Gas Engine, etc., Mechanical Engineering Drawing, and work in the Engineering Laboratories. In all of these the work is so planned as to furnish a drill in the fundamental principles of Engineering, which shall serve as a foundation for the future work of the student, whatever may be his special department.

It is noticeable that nearly all of the graduates are pursuing occupations for which their scientific training has fitted them, the exceptions forming a very small percentage of the total. For a complete list see the *Register of Graduates*, which appears in March, and which will be sent on application to the Secretary of the Faculty.

ADMISSION.

The prospective student should bear in mind that the greater his power of concentration and of independent thought, the broader his intellectual training in any direction, and the more extensive his general acquirements, the greater will be the advantages that he may expect to gain from his Course at the Institute.

For the conditions of entrance to the first, or to any other year, the Catalogue of the Institute should be consulted.

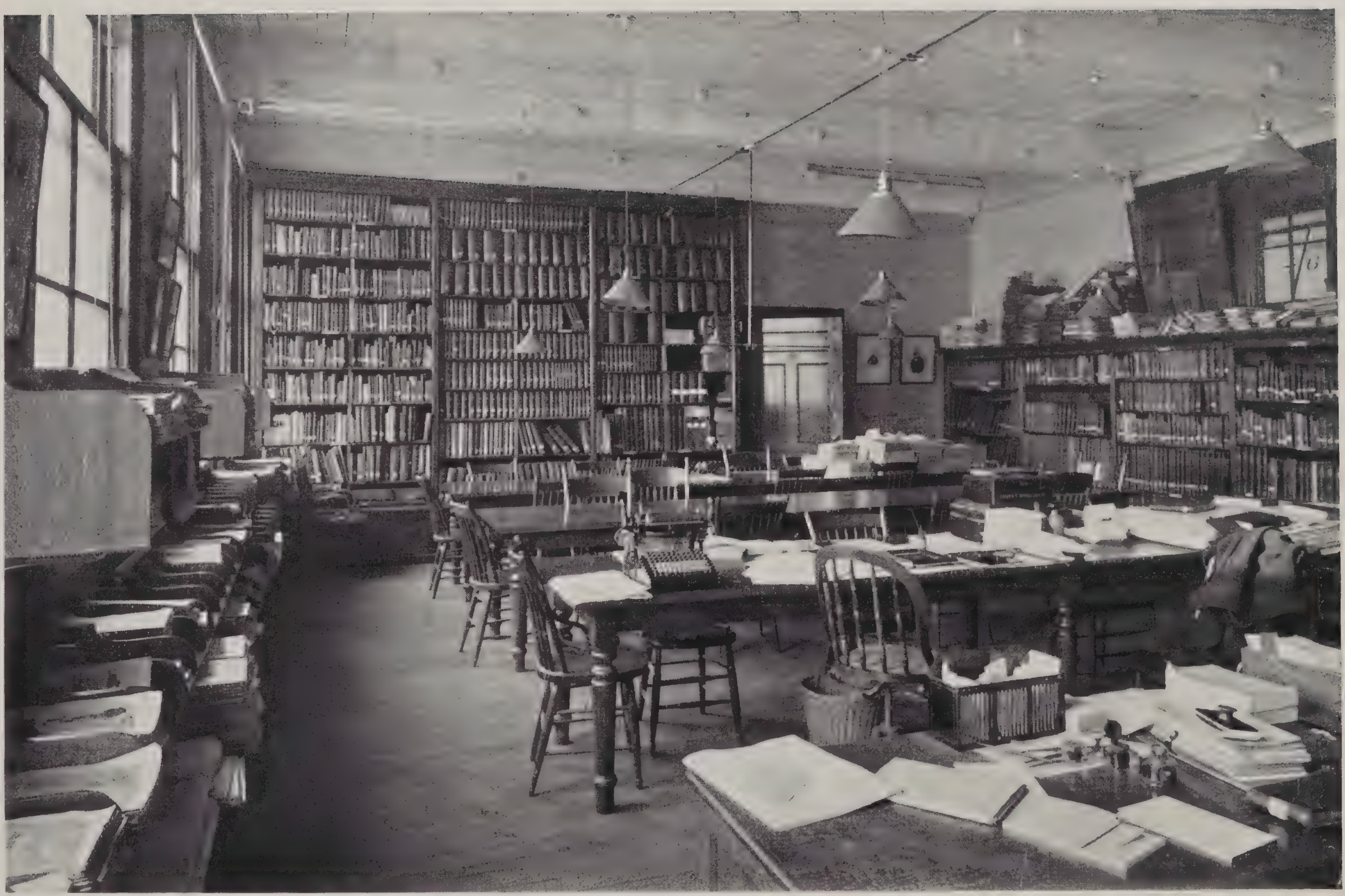
COLLEGE GRADUATES.

Graduates of colleges are admitted without the usual entrance examinations, and will be permitted to enter at such a point as their previous range of studies will allow.

If prepared to enter upon most of the studies of a certain year, they may often be afforded opportunity to make up any studies of the earlier years in which they are deficient. They will, in general, be credited with all subjects in earlier or later years in which they can show, by examination or otherwise, a standing satisfactory to the Faculty, and may be received provisionally as regular students, subject to making up deficiencies in work of previous years within a limited time.

In order to enter the Mechanical Engineering Course in the second year, it is essential that applicants have preparation in Analytic Geometry and the elements of the Calculus, and highly desirable that they be familiar with Mechanical Drawing and Descriptive Geometry. For admission to third-year engineering work, they must be prepared in Mathematics through the Calculus, in Mechanical Drawing, in Descriptive Geometry,

SECONDE-YEAR DRAWING-ROOM.



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in Physics, and in that part of Applied Mechanics given in the second year. Summer courses of appropriate scope are offered in most of these subjects, and applicants proposing to enter with advanced standing are advised to correspond with the Secretary of the Faculty in regard to their credits as early as June 1, if in doubt as to what studies, if any, should be pursued during the summer preceding entrance. Applicants desiring excuse from any portion of the physical laboratory work should present their original laboratory records. Those desiring excuse from Mechanical, or Freehand Drawing should submit examples of their work besides presenting official records.

CHOICE OF COURSE.

Regular students at the Institute are expected to choose their professional courses at the close of their first term. In considering the propriety of undertaking the Course in Mechanical Engineering, it should be borne in mind that, of the subjects studied in the first and second years, those most vital to success are Mathematics, Physics, and Drawing (including Descriptive Geometry). All the later professional work of the Department is so completely dependent upon these branches that no student can expect to succeed without having mastered them. However much interest the student may have in machinery in motion, when he attempts serious engineering work he must have a firm grasp of these fundamental subjects.

METHODS OF INSTRUCTION.

Instruction is given by lectures and recitations, and by practical exercises in the laboratories and the drawing-rooms. A high value is set upon the educational effect of these exercises as they are of fundamental importance to the Course. Text-books are used in many subjects, but not in all. In many branches the instruction given differs widely from available text-books; and, usually in such cases, notes on the lectures and laboratory work have been printed, either privately or by the Institute, and are furnished to the students at cost. Besides the ordinary exercises, written examinations are held from time to time. Near the close of the months of January and May general examinations are held. After the examinations the standing of the student in each distinct subject is reported to his parent or guardian. These reports of standing are based to a very large extent upon the quality of daily class-work. The January and May reports form the basis of admonition or advice from the Faculty in the case of students who are not profiting sufficiently by their connection with the school.

PROFESSIONAL WORK OF THE COURSE.

The professional work of the Course in Mechanical Engineering may be classified as follows:—

(*a*) Class-room work of the Department proper.

(*b*) Drawing.

(*c*) Work in the Engineering Laboratories.

(*d*) Mechanic Arts.

(*e*) Visits to engineering works and manufacturing establishments.

The instruction in Mathematics extends through the Integral Calculus, and includes, also, a course in Differential Equations. The work in Physics includes not only a treatment of the mechanics of solids, of liquids, and of gases, Molecular Mechanics, Wave-motion, Electricity, Optics and Heat, but also a course in physical laboratory work.

Passing over the first year, in which the work of the different Courses is mainly introductory and not greatly differentiated, and the subjects of Mathematics and Physics, which have already received notice, the more technical or strictly professional subjects are as follows:—

SECOND YEAR.

(*a*) *Mechanism.*—The course includes a systematic study, not only of the motions and forms of the various mechanisms occurring in machines, and the manner of supporting and guiding the parts, independently of their strength, but also of the design of gear-teeth, and the study of the mechanisms found in modern American machine-tools, and in cotton machinery.

The course also includes the theory and practice of designing valve-gears for steam engines, including the plain slide valve, link motions, radial valve-gears, double valves, and drop cut-off valves.

(*b*) *Drawing.*—The course begins with the drawing of simple machine details, such as bolts and nuts, screws, springs, keys, flanges, pipe fittings, etc., teaching standards, conventional representations, systems of dimensioning, blue printing, and the drawing necessary in connection with the course in Mechanism and Valve-gears, including problems in belting, the design of cams, quick return motions, gear-teeth, slide valves, the Stephenson link, etc.

(*c*) *Mechanic Arts.*—The instruction in Mechanic Arts includes Carpentry and Pattern-making. For further details see page 37.

(*d*) *Applied Mechanics.*—This course commences in the second term of the second year, and continues through the third year, and the first term of the fourth year. The methods of the Calculus are freely employed throughout.

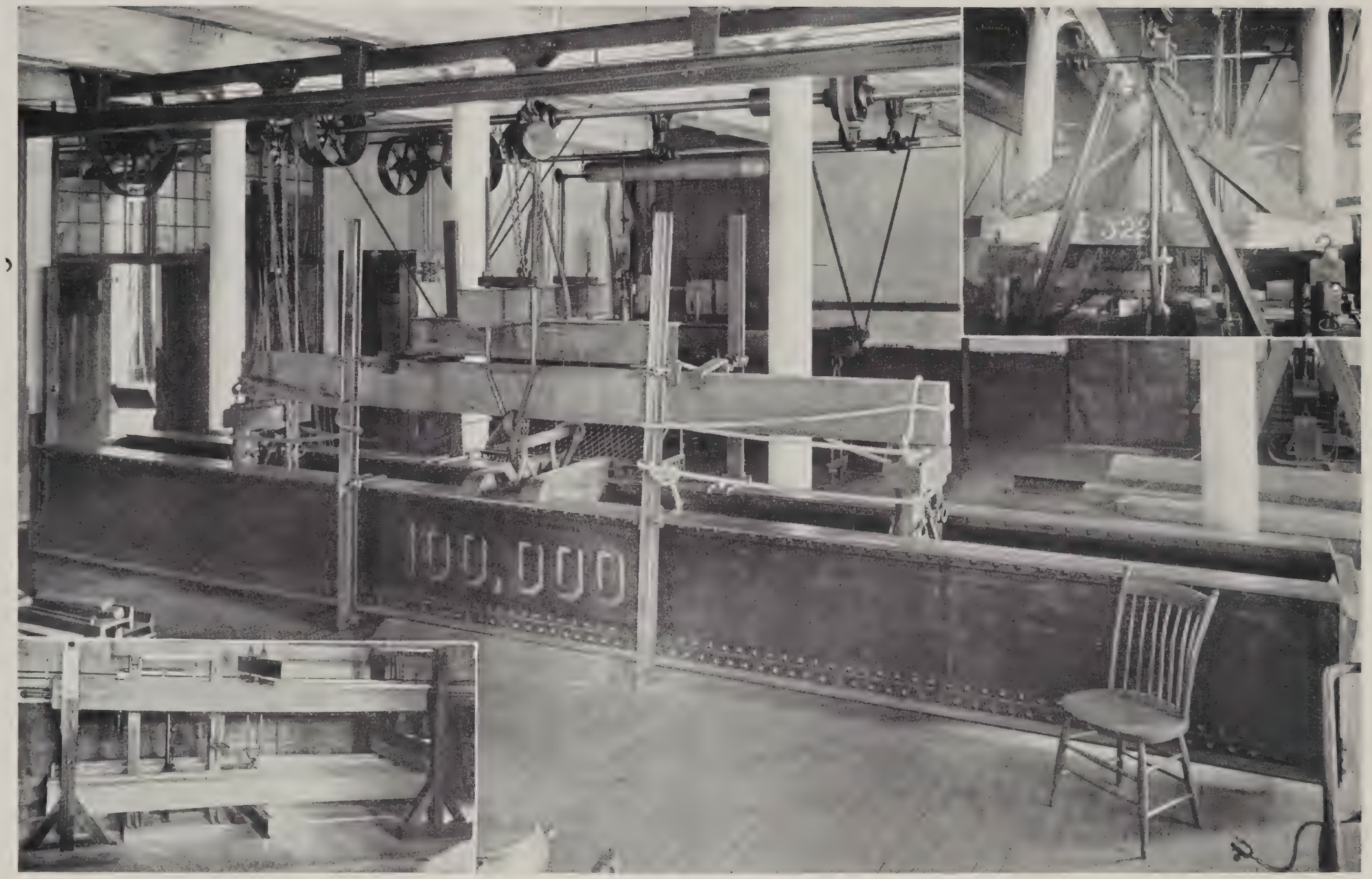
The work of the second year in Applied Mechanics comprises a study of statics, consisting of the general methods and applications of statics including the determination of reactions, stresses in frames; of distributed forces, centre of gravity; of moment of inertia, radius of gyration of plane areas and solids including principal axes and principal moments of inertia; of kinematics and dynamics including the equations for uniform and varying rectilinear and curvilinear motion, centrifugal force, unresisted projectile, pendulum, harmonic motion, rotation, combined rotation and translation, momentum and angular momentum, centre of percussion, impact, work, power and kinetic energy.

THIRD YEAR.

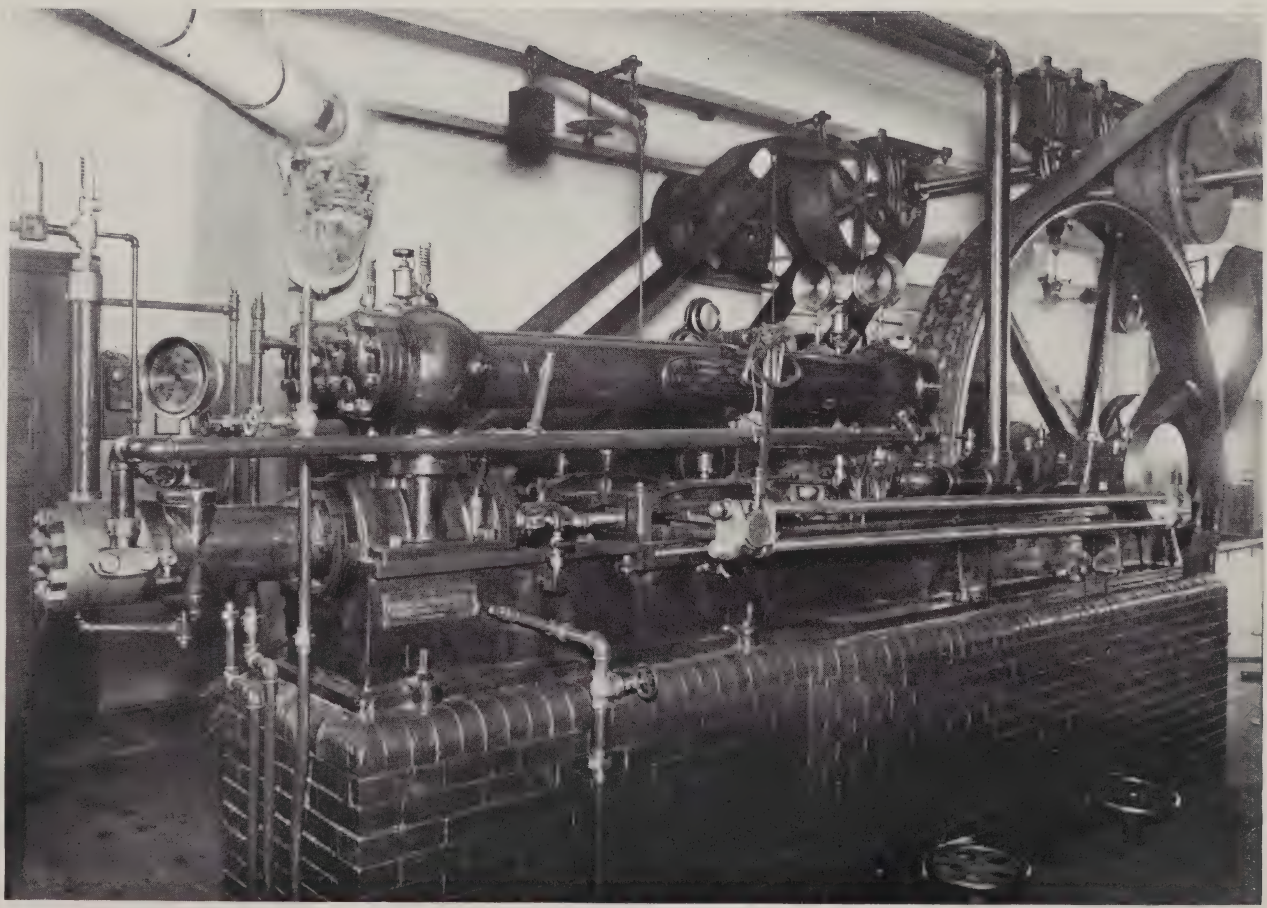
(*a*) *Applied Mechanics.*—This course is a continuation of the work given in the second year, and comprises a study of the strength of materials, mathematically treated, including the stresses and strains in bodies subjected to tension, to compression, and to shearing; common theory of beams with thorough discussion of the distribution of stresses, shearing forces, bending moments, slopes, and deflections; stresses in hooks, in columns and in beams subjected to tension or compression as well as bending; torsional stresses; stresses in springs; graphic statics, consisting of a presentation of general methods, involving the force and funicular polygons, followed by a variety of applications to roof-trusses, including the three-hinged arch.

It also includes a detailed study of such data on the strength of materials as have been obtained by means of experiments, especially those upon full-sized pieces, and under practical conditions, in different parts of the world. Moreover, this work is constantly revised, and brought up to date, as later experiments throwing new light upon the subjects are made. The subjects treated are as follows: *Cast iron*—Specifications in the case of the standard test specimens; tensile, compressive, and transverse tests, including tests of full-sized columns, of window lintels, and of pulley arms. *Steel and Wrought iron*—Specifications in the case of the standard test specimens, and also in the case of large bars; effect of temperature; tests of repeated tresses, including the work of Wöhler, of Bauschinger, and others; test of full-sized bridge columns, of I-beams, etc.; tests and design of riveted joints; tests of shafting subjected to both twisting and bending; tests of full-sized timber beams and columns; tests of timber framing-joints, headers, etc.; test of timber in shearing, and when subjected to compression across the grain; tests, specifications, etc., of cement, and of concrete, including tests of concrete beams and columns.

In connection with this work the students are required to



BEAM TESTING MACHINE AND TIME TEST APPARATUS.



THREE-STAGE AIR COMPRESSOR.

make tests of materials in the Applied Mechanics Laboratory, the tests made by them in 1907–1908 being the following:—

A test to determine the modulus of elasticity, the limit of elasticity, yield point and the tensile strength of a wrought-iron, or a steel rod or bar.

A test of the deflections and of the transverse strength of a full-sized iron or steel I-beam, or of a wooden beam subjected to a transverse load.

A transverse test on cast-iron.

A test to determine the modulus of elasticity and the tensile strength of wire.

Torsional tests of wire.

A test to determine the shearing modulus of elasticity and torsional strength of 2-inch iron or steel bars.

Tests on cement and cement mortars including practice in laboratory methods.

Tests of the strength of different kinds and sizes of ropes and of different knots used in fastening ropes.

Tests to determine the ratio of the modulus of rupture to the tensile strength in bars of Bessemer steel of different sections.

The crushing strength of short struts and of wooden columns.

The above is followed by a course on the Theory of Elasticity which includes the determination of the resultant strains in any direction, as well as the stresses on any plane in both single and compound stress, the relation between stresses and strains, together with a consideration of the Poisson ratio; the determination of the principal stresses; and applications to shafting subjected to twisting and bending combined, hydraulic presses, flat plates, earth-work, etc.

(*b*) *Steam Engineering.*—This course includes a detailed study of the principles of Thermodynamics mathematically treated; a discussion of the properties of gases and vapors, especially steam; of the flow of steam and other fluids; of the steam injector; and of the hot air engine and gas-engine. All these topics are treated in such a way as to give the student a good foundation in the principles of Thermodynamics, especially as they apply to the steam-engine and steam-turbine. This is followed by a study of the steam-engine itself, of the compound and multiple expansion engine, and of the mode of testing steam-engines, of compressed air, and of refrigerating machines. A careful study is made of such data as have been based on reliable tests made on large, single, compound, and multiple expansion reciprocating engines, and on the steam-turbines.

The subject of steam-boilers is treated at considerable length. Several lectures are given on condensers, air-pumps, and the various accessories of a steam plant.

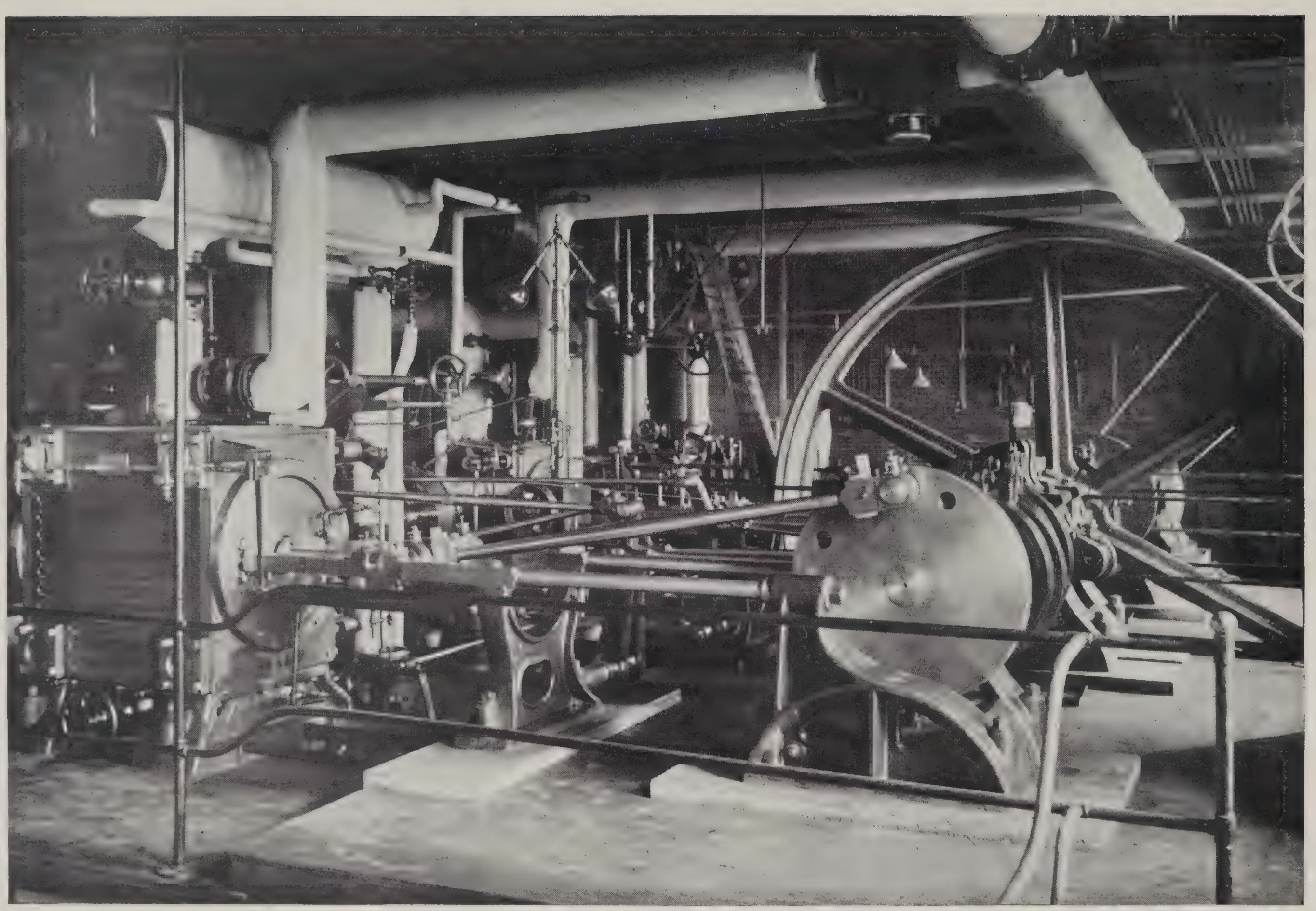
(c) *Drawing.*—The course in Machine Drawing aims to teach the proper way of making the necessary dimensioned drawings for use in practice, good shop systems being adopted. The instruction includes the making of working detail and assembly drawings of machinery from measurements. This course is followed by practice in the solution of problems in Mechanism Design, such as special valve-gears, quick return motions, etc., some time being also spent in the determination of velocity diagrams for special engine or other linkages.

A course in Boiler Drawing is given in connection with the class-room work in boilers, and is intended not only to teach the method of drawing boilers, but to give the students more familiarity with the construction and details of steam boilers. In this course the first problem in Machine Design is begun.

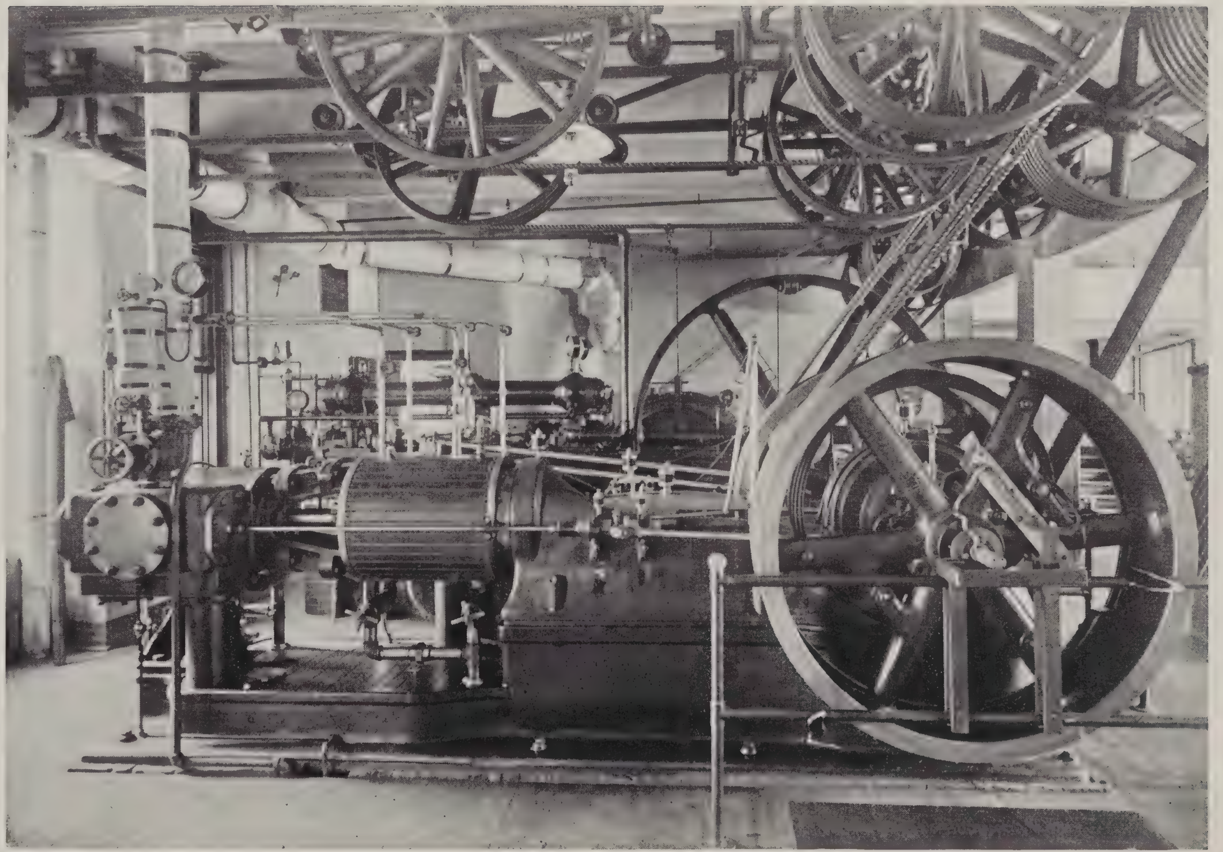
(d) *Electrical Engineering.*—This work consists of:—

1. A course of thirty lectures in which are considered the fundamental principles of the generation, distribution, and utilization of electrical energy.
2. A course of thirty lectures and recitations on technical electrical measurements and methods, followed by a discussion of electric installations.
3. A course of laboratory exercises designed to familiarize the students with the elements of technical electrical measurements.

(e) *Engineering Laboratory Work.*—This work is given during the second term, and is devoted to drill in steam-engine tests, for which a 9-inch, 16-inch, and 24-inch by 30-inch triple expansion engine, an 11-inch, and 19-inch by 15-inch tandem compound engine, an 18-inch, and 32-inch, by 24-inch compound engine, and a 14-inch, and 23-inch, by 16-inch tandem compound engine are used. In these engine tests the



TRIPLE EXPANSION ENGINE,—CORLISS TYPE.



TANDEM COMPOUND HIGH-SPEED ENGINE.

water consumption is determined by condensing and weighing the steam after it has passed through the engine.

(*f*) *Mechanic Arts.*—The instruction in Mechanic Arts of the third year includes Forging and Chipping and Filing. For further details see page 37.

FOURTH YEAR.

The work of the first three years, as already described, is taken by all students of the Course in Mechanical Engineering. In the fourth year five Options are offered, Marine Engineering, Locomotive Construction, Mill Engineering, Heating and Ventilating Engineering, and Steam Turbine Engineering, of which one is required.

The following fourth-year subjects are pursued by all students:—

(*a*) *Applied Mechanics.*—This course extending through the first term includes a study of the continuous girder, so planned as to apply to beams and also to parts of machinery where there is a transverse load, and where continuity exists; a graphical treatment of the masonry arch; and a mathematical treatment of the elastic arch. The latter part of the course deals with the subject of friction and treats of the methods of making the usual calculations, including those for the work used up in friction in journals and in pivots, under each of the two assumptions commonly made as to the distribution of the pressure, and also the calculations for belt and rope transmission for rollers, etc. Subsequently comes a study of the experimental work that has been performed upon journals, pivots, belting, etc., and upon the friction-reducing power of lubricants, and the theory of lubrication.

(*b*) *Machine Design.*—To this work are devoted, including all time used for lectures, calculations and drawings, six hours per week during the first, and four hours per week during the second term of the fourth year. The main object of the course is the application of principles already learned to the solution of problems in design. Each student makes a number of complete designs, such as a boiler, a large shaft with pulleys and gears, a set of couplings, etc. The constructive details of all designs are carefully discussed, and each student then makes all the necessary calculations to determine the dimensions of every part, not by the use of empirical formulæ, but by means of principles already acquired, and finally he completes the working drawings. The scope of the designs is such as to include most of the elementary principles of design, and yet is sufficiently limited to enable the student to complete every detail, for it is believed that only by such thorough work can real benefit be obtained.

(*c*) *Steam and Hydraulic Laboratory Work.*—This work can be best illustrated by the following list of the tests made by the students during the past two years:—

Tests of the transmission of power by belting.
Tests of the performance of a surface condenser.
Tests of a duplex steam pump, sixteen, and ten and one-half by twelve inches.
Tests to determine the accuracy of planimeters.
Tests of a thirty-six horse power gas engine.
Tests to determine the efficiency of pulley blocks.
Tests of the flow of steam.
Valve setting (plain slide valve).
Tests of a pulsometer.
Calibration of orifices for the flow of water.
Determination of the clearance of an engine.
Use of the Emerson power scale.
Valve setting (double valve).
Tests of gauges, steam and vacuum.
Test of a four hundred horse power battery of boilers, the test continuing for 104 hours, each man working eight hours.
Tests of the steam injector.
Use of three different kinds of calorimeters.
Tests of a Swain turbine.
Tests of a rotary pump of a capacity of one thousand gallons per minute.
Tests on the flow of air, through orifices and nozzles up to two inches at the throat, and with pressures up to three hundred and fifty pounds per square inch.
Tests of a seven and one-half horse power De Laval steam turbine.
Tests of the steam ejector.
Tests of the water ejector.
Tests of a thirty-six-inch American impulse wheel.

Tests of an air-pump.

Tests on coefficient of friction.

Moment of inertia of connecting rod.

Tests of three stage air-compressor, twenty-five hundred pounds pressure per square inch.

Measurement of the flow of water by means of orifices and weirs.

Tests of a forty-eight-inch Pelton water wheel.

Tests of a Rider hot-air engine.

Tests of an Ericsson hot-air engine.

Valve setting (Harris-Corliss engine).

Analysis of chimney gas.

Explosive force and time of reaching maximum pressure of different mixtures of gas and air.

Ratio of specific heats of air.

Application of Hirn's analysis to the triple expansion engine in the laboratory.

Tests of a Rite Hydraulic Ram with a four-inch drive pipe.

In addition to the above, the students have eight hours' work in the laboratory for the study of the heat of combustion, determining heating values of coals, taking high temperature measurements and doing other work of this class.

The method of conducting these laboratory tests is as follows:—

Tests are made under the direction of eleven instructors, three students generally working together on one test. Since the students are applying in their laboratory work knowledge they have already gained in the class-room in professional subjects, it is only necessary for the instructors to explain the arrangements of piping and connections for any piece of apparatus before work is begun. This makes it possible for a great deal of valuable laboratory work to be done in a period of two hours.

The observations taken on any test are recorded on a printed log sheet, which is returned to the instructor. Each student working on any test copies from this large log upon a small printed log sheet the data needed in calculating the results of that test. These small log sheets have attached to them a number of pages for calculation and for remarks. The student, after computing a test, hands the log sheet to an instructor, who compares it with his own calculation.

(*d*) *Hydraulics and Hydraulic Motors.*—This work is a series of thirty exercises during the second term of the fourth year, mainly recitations based upon a text-book, and is to some extent a continuation of the brief course in Theoretical Hydraulics, so as to embrace the laws of flow in open channels and of the dynamic pressure and work of water flowing over curved surfaces. The time is principally given, however, to a study of impulse wheels and reaction turbines, with reference to their proper construction, regulation, and testing, and to the various sources of loss of energy in their operation. Lectures on speed regulation are given by a specialist in that line of work.

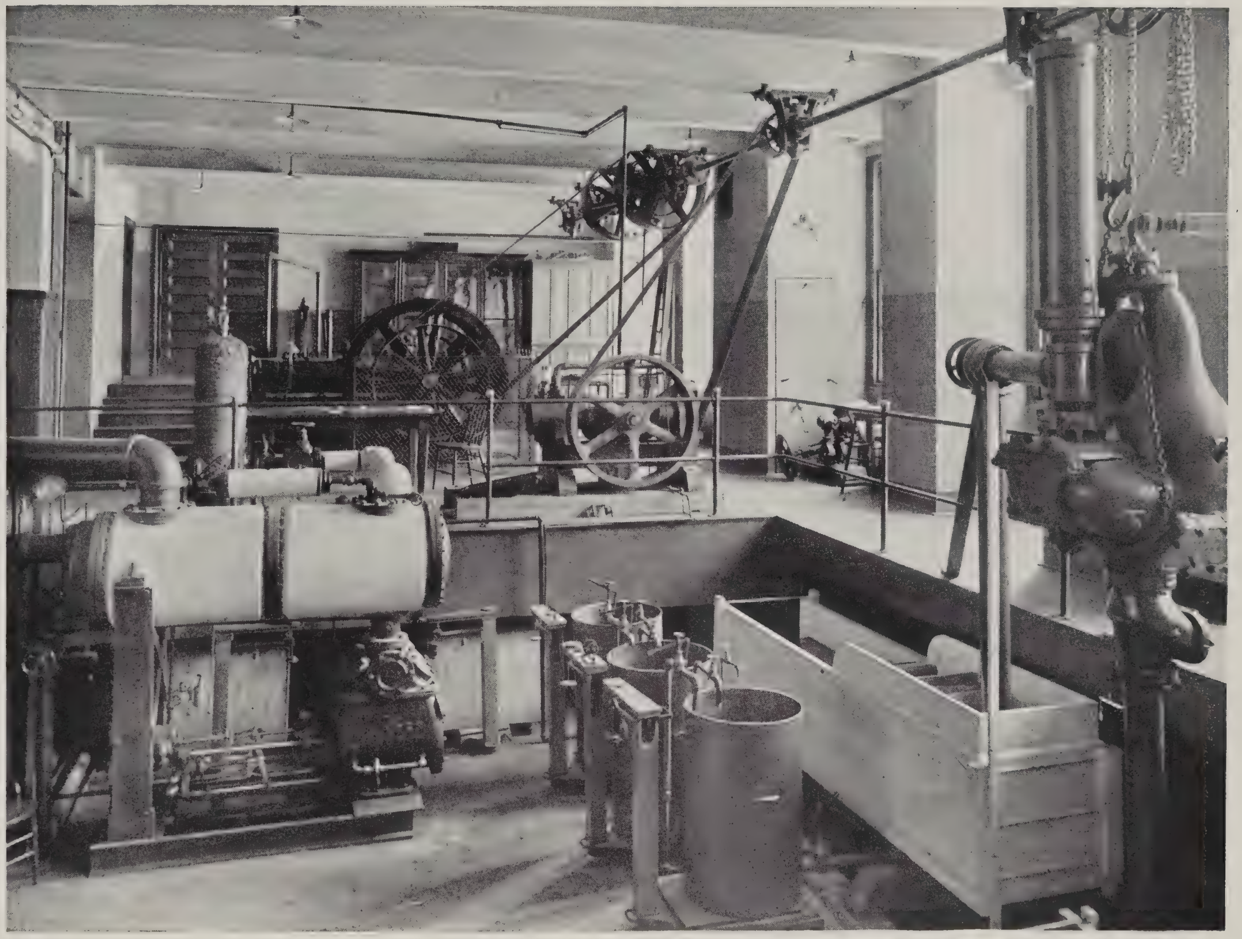
(*e*) *Power Plant Design.*—This work consists of the design of a steam plant of a mill or factory, and of making the necessary calculations and drawings for the same.

(*f*) *Foundations.*—The subjects treated in this course are as follows:—building stones and concrete; bearing power of soils; examination of the site; designing the footings, whether of masonry or of steel and concrete; independent piers; pile foundations; compressed air processes; freezing processes; and retaining walls.

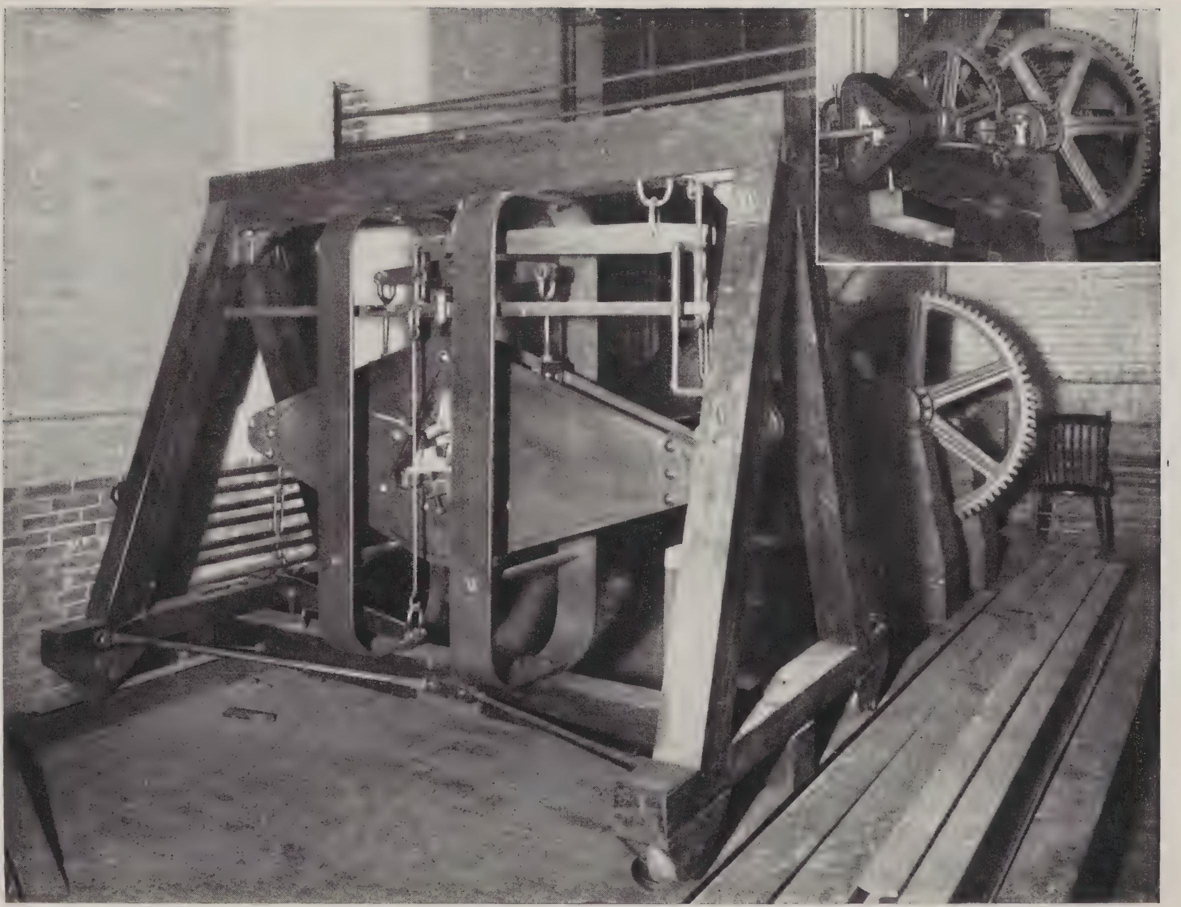
(*g*) *Industrial Management.*—This course of ten lectures in the second term of the fourth year includes a study of the organization and relations of the various departments of an industrial establishment, both in the office and in the workshop; the conduct of accounts; the methods of superintendence and of compensating labor; the determination of costs of production; and a careful discussion of the effect on costs of different systems of distributing indirect expenses.

(*h*) *Dynamics of Machines.*—This course includes a number of the principal applications of dynamics to moving machinery, as governors, fly-wheels; the action of the reciprocating parts of the steam-engine; the balancing of machinery, including reciprocating engines; and the securing of a running balance in machinery revolving at high speeds, as steam-turbines, etc.

The various subjects are treated in such a manner that the



PORTION OF ENGINEERING LABORATORY. (PIERCE BUILDING.)



TORSION TESTING MACHINE. Capacity, 150,000 inch-pounds.

results are suitable for practical use in designing and also in making experimental investigations.

(*i*) *Mechanic Arts.*—The instruction in Mechanic Arts includes Foundry Work and Machine-tool work. For further details see page 37.

MARINE ENGINEERING.

The Option in Marine Engineering begins with a thorough study of the problems of the resistance and propulsion of ships, leading to the determination of the power required for a certain speed, and the methods of designing and proportioning paddle-wheels and screw propellers. A description is given of marine engines in all their details, together with methods of determining dimensions and proportions of parts and the stresses due to steam pressure and dynamical actions.

A discussion is given of vibrations of ships and balancing engines. Each student makes a preliminary design of a marine engine and the design for propellers suitable for such an engine.

LOCOMOTIVE CONSTRUCTION.

The Option in Locomotive Construction begins with a careful study of the form and proportions of the details of the more usual types of locomotives. Sets of complete detail drawings of modern locomotives, both simple and compound, are used for this purpose, a considerable number of such drawings having been furnished to the Department by different locomotive builders. While most of these are American, nevertheless, consideration is given also to those of foreign construction. The students make calculations of the stresses to which the various parts are subjected, when in service, and thus learn to determine the strength of the different members, modern locomotives being used for this purpose. A study is made, also, in some detail, of the compound locomotive, of train resistance, of air-brakes, of heating cars by steam from the locomotive, of the modes of conducting locomotive tests, of the economy and performance of both simple and compound locomotives, as shown by tests, etc.

MILL ENGINEERING.

The Option in Mill Engineering includes the study of mill and building construction and stability; chimney construction and design; the calculation of stresses in an existing modern mill building from working drawings; a discussion of cotton mill organization and equipment, including the economical arrangement and methods of driving machinery; a study of the different methods of distributing power, the design of the power plant, and determination of cost of power; all leading up to the solution of a problem involving the design of a complete mill plant.

HEATING AND VENTILATING ENGINEERING.

The Option in Heating and Ventilating Engineering includes studies relating to the hygiene, the economics, and the methods of ventilation; the treatment of air preparatory to its use in ventilating work; the mechanics of ventilation; the mechanism for ventilating work, including electric generators, electric, steam, water, and other motors and blowers; air analysis and its use in testing ventilating work; the relation of fuels, chimneys, and the various types of furnaces to heat production and utilization; the determination of the calorific power of fuels; the rates of heat-loss by buildings; the methods of warming buildings by hot air, water, and steam; and the various types of buildings, with reference to the most effective methods of warming and ventilation.

STEAM TURBINE ENGINEERING.

The Option in Steam Turbine Engineering gives a discussion of the arrangement and construction of various types of steam turbine, and methods of determining sizes and proportions required for the development and distribution of power, and to secure sufficient strength and favorable conditions for operation.

THESIS.

The thesis required of every candidate for graduation involves an investigation of some engineering problem or an original design. In connection with the theses a large amount of investigation is carried on under the direction of some member of the instructing staff; and it is partly by means of this work and partly by means of the regularly assigned laboratory work that the Department is enabled to carry on a large amount of original research (mostly experimental) in Mechanical Engineering subjects. All theses and records of work done in preparation of theses are the permanent property of the Institute, and cannot be published, either wholly or in part, except by the authorization of the heads of the respective Departments.

Some knowledge of the character of the thesis work can be gained from the titles of the theses of several classes which are given on pages 39–48.

SPECIAL LECTURES AND EXCURSIONS.

In connection with the regular work of the Course, visits are made to machine shops and manufacturing establishments where machinery may be seen in operation as well as manufacturing processes more extensive than would be possible at the Institute.

Besides the teaching by the regular corps of instructors, lectures upon special subjects are given by engineers actively engaged in the profession. It is believed that these lectures and the occasional contact with men from the outside world are beneficial to the students.

SOCIETY OF ARTS.

In addition to the preceding lectures, the meetings of the Society of Arts are always open to students. Professional papers are read before the Society of Arts semi-monthly, on matters of scientific and technical interest, the aim of the society being to awaken and maintain an interest in the practical applications of the sciences and to aid in their advancement.

REQUIREMENTS FOR GRADUATION.

The degree of Bachelor of Science in the Course is given for the satisfactory completion of the regular course of study.

To be entitled to a degree, the student must have attended the Institute for not less than one year, which must be that immediately preceding his graduation, except as postponement may be specially authorized. He must have completed the prescribed studies and exercises of the four years, and must, in addition, pass final examinations, if required, on subjects relating particularly to his Course. He must, moreover, prepare a satisfactory thesis.

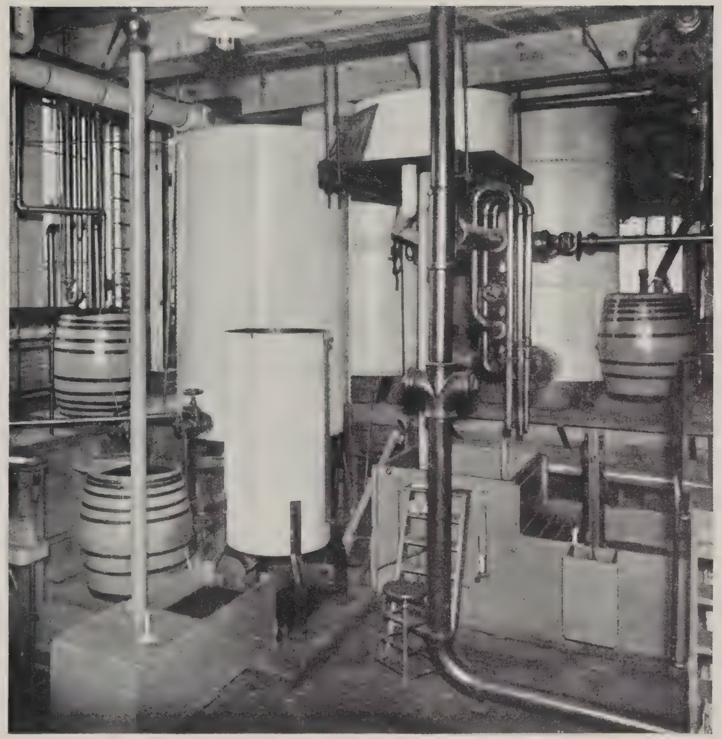
DEGREES IN RELATED COURSES.

The continually increasing specialization of the various engineering professions and the upward tendency of the standards of professional attainment render it difficult in a four-year Course to give much more than a thorough training in the student's chosen specialty. Hence it is frequently of great advantage to a graduate from one of the Engineering Courses to devote an additional year to the professional work of another closely related Course. A knowledge of more than one branch of science or engineering is so often required in professional practice that men who have received the double training which is given by such Courses are particularly well fitted to deal successfully with large industrial and engineering problems.

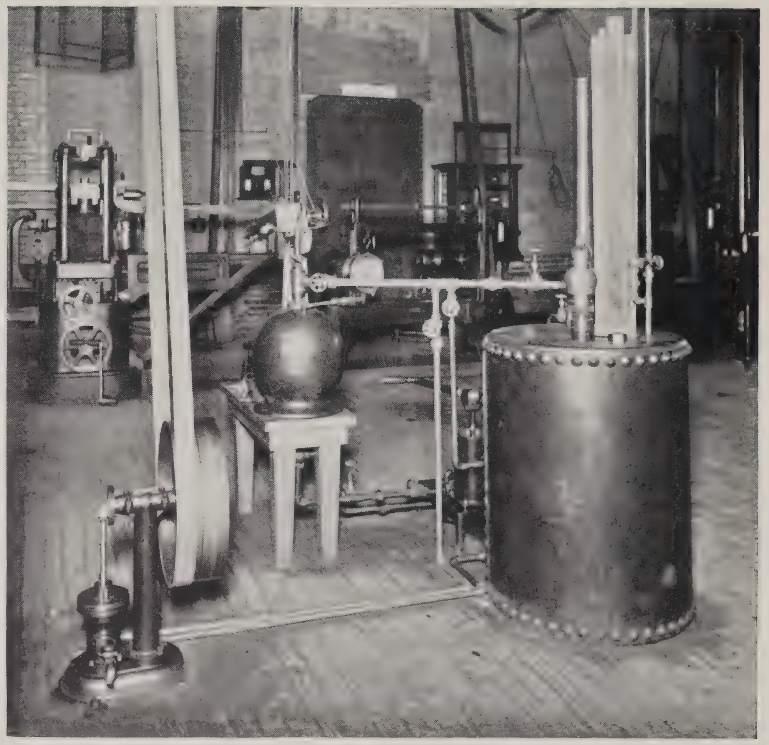
GRADUATE COURSES.

The Institute offers courses of advanced study and research leading to the degrees of Master of Science, Doctor of Philosophy, and Doctor of Engineering.

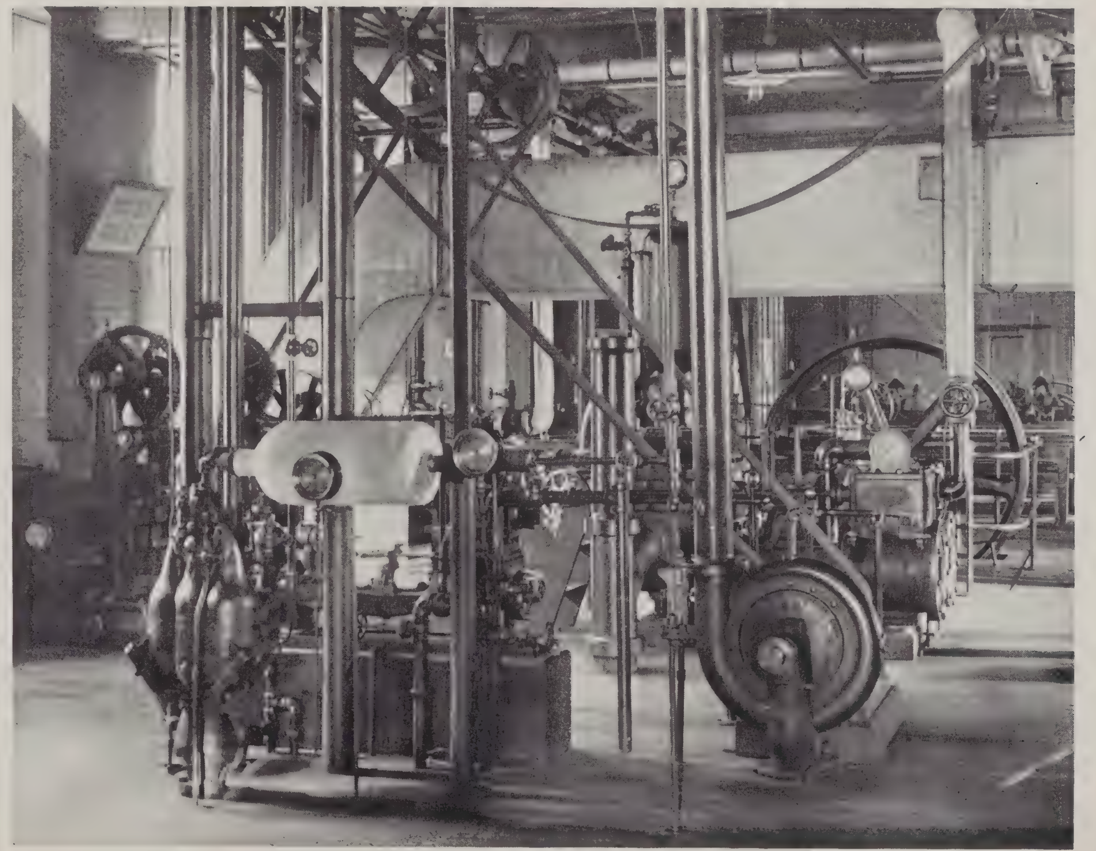
An applicant for any of these degrees must, except in cases



PORTION OF SUB-BASEMENT SHOWING MEASURING TANKS.



GAS EXPLOSION APPARATUS.



PORTION OF ENGINEERING LABORATORY SHOWING SEVERAL OF THE PUMPS.

of unusual attainment, have taken his first degree in some scientific school, college, or university of good standing; and his attainments must be substantially equivalent to those required for the Bachelor's Degree of the Massachusetts Institute of Technology. Only those applicants will be accepted as candidates for an advanced degree whose attainments, as shown by their previous record of scholarship, or by other information, are of such a character as to indicate that their proposed course of advanced study and research can be creditably pursued. He must file with the Secretary of the Faculty, before being accepted as a candidate, a statement of his previous work and present attainments, and of the advanced work which he intends to do at the Institute.

Advanced courses in chosen lines of study, without reference to degrees, may be pursued by graduates of the Institute without preliminary examination, or by graduates of other institutions who satisfy the Faculty that they are qualified to take with advantage the courses proposed.

Further information regarding graduate work may be found in the circular on Advanced Study and Research, which will be sent on application to the Secretary of the Faculty.

MASTER OF SCIENCE.

The course of study leading to the degree of Master of Science must consist mainly of advanced study and research. The candidate must pursue his course of study continuously, under the direction and oversight of the Faculty, for at least one full year after filing his application, exhibiting during that time ability to conduct original investigations. He must pass creditable examinations at such times and on such subjects as may be designated, and finally must present an acceptable thesis.

Such an advanced course serves to supplement the undergraduate work by more thorough instruction in underlying principles and their mathematical development, by a fuller study of special branches of the profession, and by a training in the investigation of scientific or technical problems, which is essential to the highest professional success.

Special Provision for College Graduates.—The Faculty desires to encourage college graduates to pursue advanced work in science and engineering, and accordingly such graduates who have completed (in general with not less than one year's residence) substantially all requirements in any Course up to the beginning of the fourth year will be allowed, subject in each case to the approval of the Faculty, to become candidates for the Master's Degree without taking the Bachelor of Science Degree, on the basis of two years of additional work.

The requirements for this work would in general include subjects in the fourth year of the regular Course and subjects chosen from the list of studies offered in the fifth or graduate year, together with the preparation of a thesis. The choice and distribution of studies constituting the schedules of both years should be made in consultation with the Head of the Department (it being understood that the work of the first year would consist mainly of the work of the regular fourth year), and the schedules should be approved by the Committee on Advanced Degrees and Fellowships or by a special committee of the Faculty.

DOCTOR OF PHILOSOPHY.

The degree, Doctor of Philosophy, certifies to the creditable completion of an advanced course of study in some branch of science and to the performance of an original research of high grade bearing upon some scientific topic. It will be awarded only to candidates who have exhibited the power of dealing with new problems in an independent and efficient manner. The study and research for the degree must be pursued under the direction and oversight of the Faculty for at least two school years. Attendance at the Institute must be continuous, except in cases of absence previously approved by the Faculty.

The courses of study leading to the degree of Doctor of

Philosophy are especially valuable to those who wish to engage in original research work or instruction in higher institutions of learning; but a thorough knowledge of scientific facts and principles and a training in methods of investigation are so essential to creative work in any branch of industry that students who are preparing themselves for an industrial career will also derive great profit from such courses.

DOCTOR OF ENGINEERING.

The increasing demand for men having not only the engineering training of the technological school, but the attitude of mind inciting them to attack new problems,—men who have not simply a basis of theoretical and practical knowledge, but who have also the spirit and the aptitude for the investigation of technical problems cultivated to a much higher degree than is possible in an undergraduate course, has led the Institute to make provision in its Engineering Departments for courses of advanced study and research leading to the degree of Doctor of Engineering. Some of the larger industrial and manufacturing establishments are already conducting independent laboratories of research where men having such advanced training are in demand.

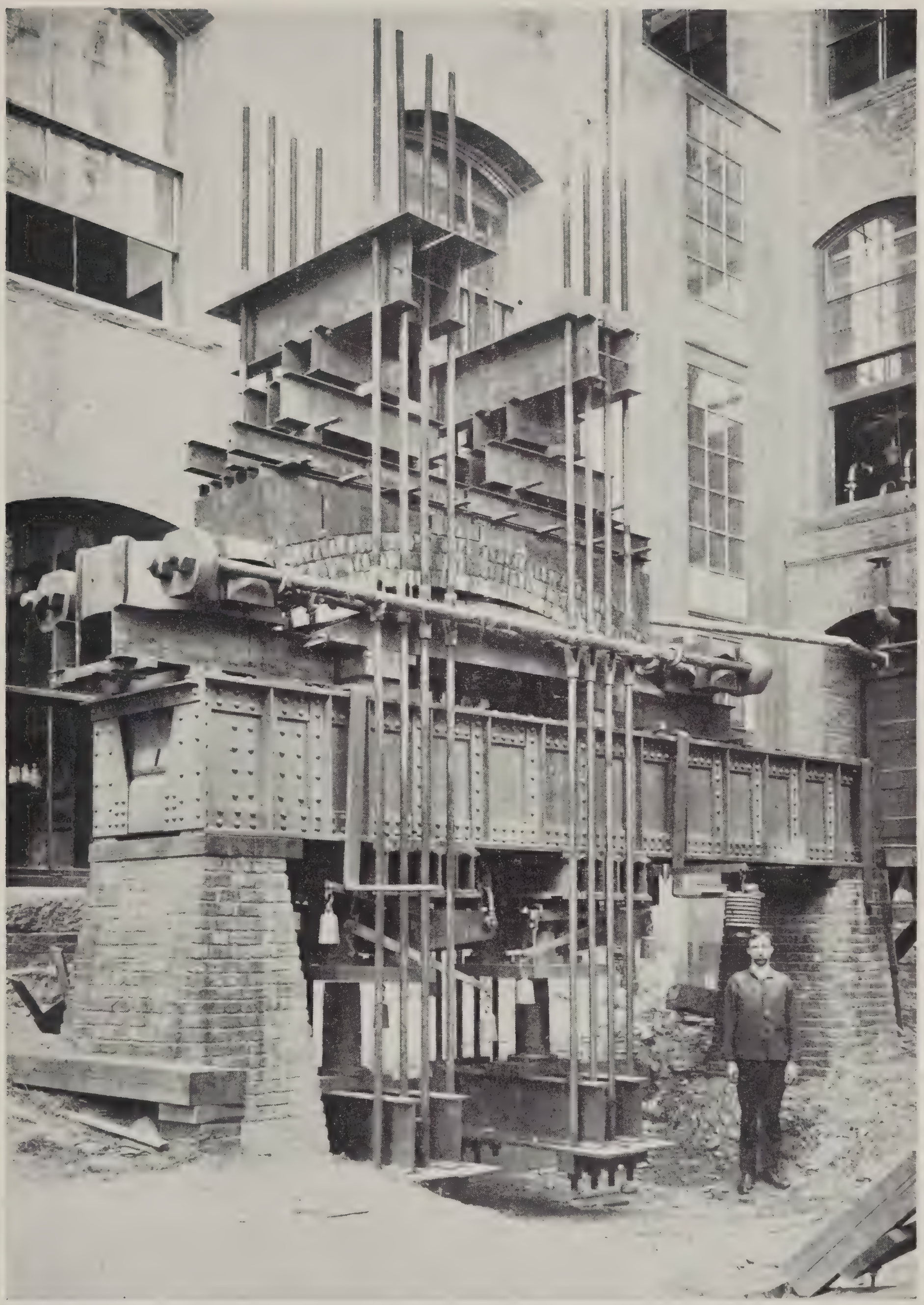
The degree of Doctor of Engineering certifies to the creditable completion of an advanced course of study in some branch of engineering and to the performance of an original research of high-grade, bearing upon some engineering topic. It will be awarded only to students who show capacity for the investigation of original problems in some branch of engineering and in some of the sciences upon which engineering depends.

In making his application for acceptance as a candidate for the degree of Doctor of Engineering, the applicant will be expected to submit a statement of the subjects of study which he desires to pursue, and to announce his choice of a problem upon which he intends to make an extended original investigation or research and to prepare a thesis. To these subjects, and especially to this problem, he will be expected to devote himself diligently and successfully throughout a period of not less than two consecutive years, during which time he shall work in residence under the direct supervision of a committee of the Faculty. Ordinarily, however, a candidate should expect to devote three years to the work for the degree. It is advisable for a candidate, not previously connected with the Institute, to qualify himself first for the Master's degree before being accepted as a candidate for the Doctor's degree. In planning his course of study the candidate should refer to the later sections of this circular entitled "Elective Subjects for Advanced Courses" and "Opportunities for Research."

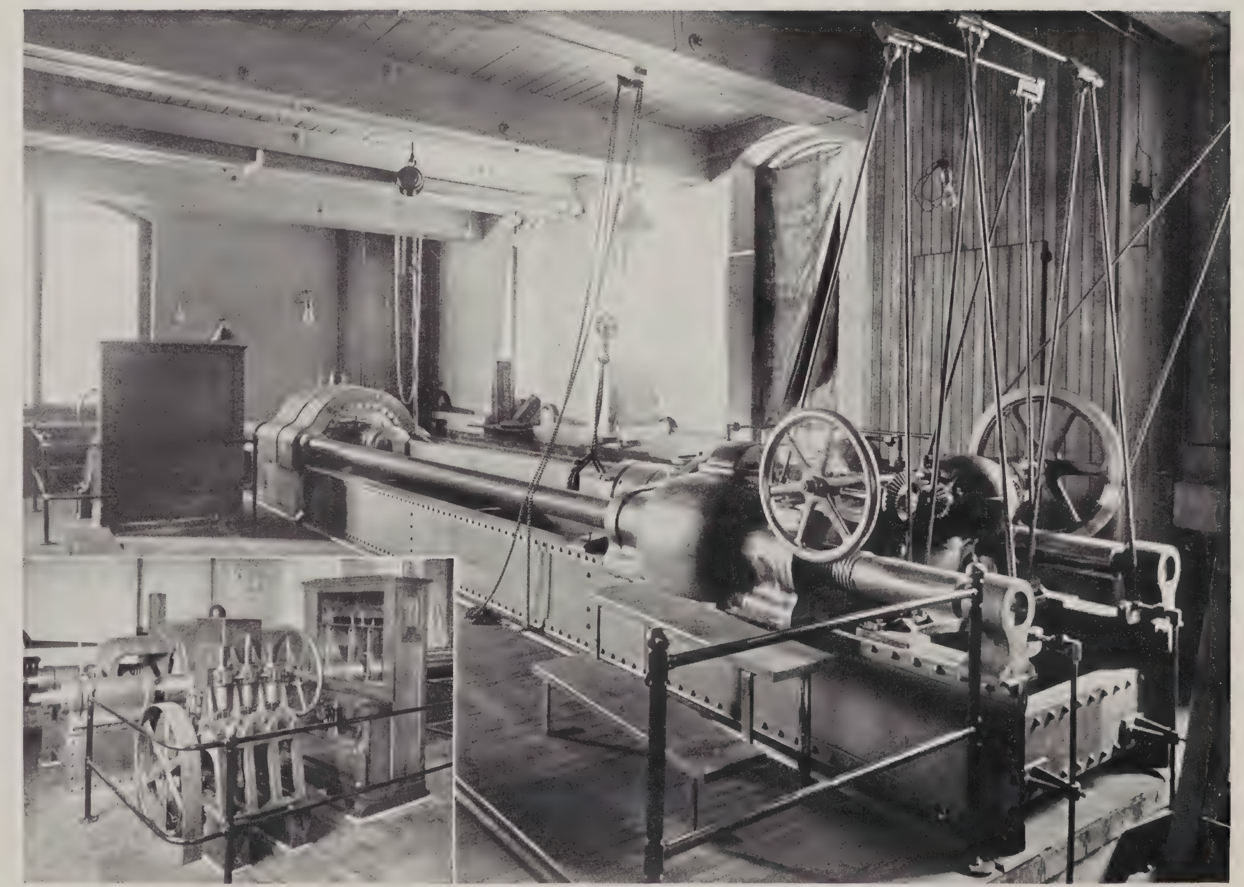
The requirements for the degree of Doctor of Engineering and the regulations in regard to it are in general similar to those for the degree of Doctor of Philosophy.

ELECTIVE SUBJECTS FOR ADVANCED COURSES.

Since the choice of the most advantageous subjects for an advanced course depends much upon individual conditions, the Faculty has not prescribed definite schedules for the higher degrees. But in order to indicate the opportunities for advanced work offered by the Institute, and in order to aid candidates for such degrees in laying out their courses of study, there have been brought together the names of such elective subjects as are considered to be especially appropriate for this purpose. A detailed description of most of these subjects will be found in the division of the Institute Catalogue entitled "Subjects of Instruction" to which the numbers in parentheses attached to the separate topics refer. These subjects have been grouped under headings corresponding to the various undergraduate Courses of the Institute, so as to indicate the lines of advanced work most suitable for a graduate of any of these Courses or for a graduate from another institution who has had an equivalent preparation. It should be understood, however, that the choice of subjects is not necessarily restricted to those grouped



MACHINE FOR TESTING FULL-SIZE MASONRY ARCHES.



TESTING MACHINE (EMERY PATENTS). Capacity, 300,000 pounds.

under any one Course; but it is in general essential that admission to any elective subject be dependent upon the applicant having had the preparation indicated in the Catalogue under "Subjects of Instruction." The necessary preparation may in a number of cases be obtained by taking courses in the Summer School or by pursuing courses of special reading during the summer prior to entrance, under the direction of the professor in charge.

The Elective Subjects in each Course are classified as follows:—

A. Major Subjects, consisting of professional studies more advanced in character and scope than the corresponding work for the degree of Bachelor of Science. The principal part of the candidate's work must be selected from subjects in this group.

B. Minor Subjects, consisting of studies selected from the fourth-year schedules of other Courses or Options in the same Course, and in exceptional instances certain third-year subjects which form, with the advanced work, a logical general program. The time devoted to subjects in this group must be less than that required for the major work.

The candidate's research and his other major subjects are to be selected with due reference to each other in consultation with the Head of the Department, and the proposed course of study must be submitted to the Faculty for approval.

FOR GRADUATES IN MECHANICAL ENGINEERING.

A. MAJOR SUBJECTS.

	Term.	Hours per term.
Research	1 and 2	
Advanced Theory of Elasticity (97)	1 or 2	100 to 200
Analytical Mechanics (96)	1 and 2	45–90
Advanced Machine Design (406)	1 or 2	100 to 200
Advanced Steam and Gas Engineering (388)	1 or 2	100 to 200

B. MINOR SUBJECTS.

Marine Engineering (420), Locomotive Construction (421), Mill Engineering (422), Heating and Ventilating Engineering (423), Hygiene of Ventilation and Heating (758), Advanced Calculus (36), Differential Equations (44), Vector Analysis (46), Fourier Series (52).

Alternating Current Machinery (650),[1] Electrical Engineering Laboratory,[3] Technical Electrical Measurements (685),[2] Standardizing Laboratory.[3]

THE ENGINEERING LIBRARY.

The libraries of the Departments of Civil, Mechanical, and Sanitary Engineering, are united into a single library under the direct charge of the Librarian of the Institute. This library contains about fourteen thousand volumes and five thousand pamphlets. It is especially rich in journals and transactions of societies dealing with the various branches of engineering. Two hundred and forty publications of this kind are received annually.

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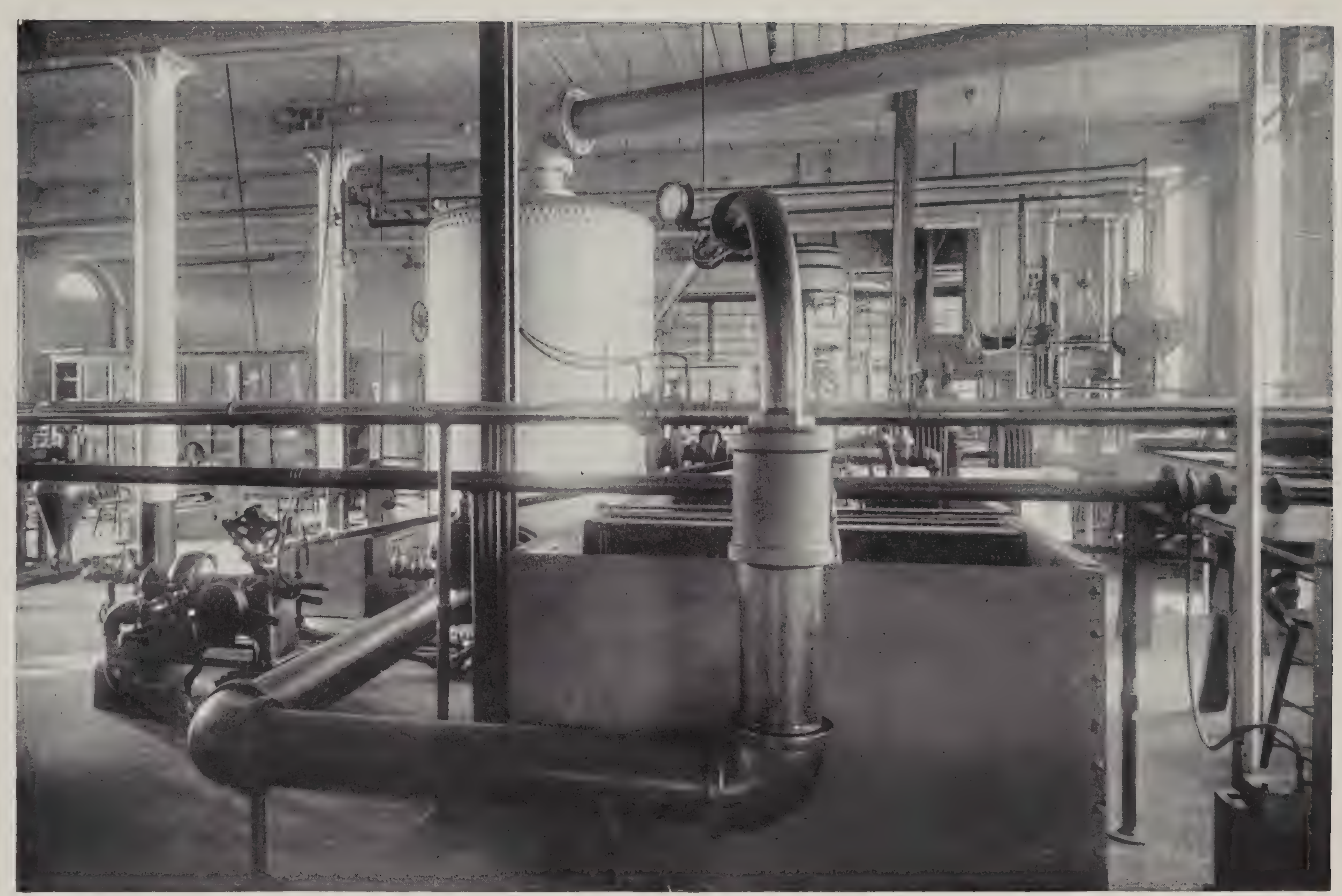
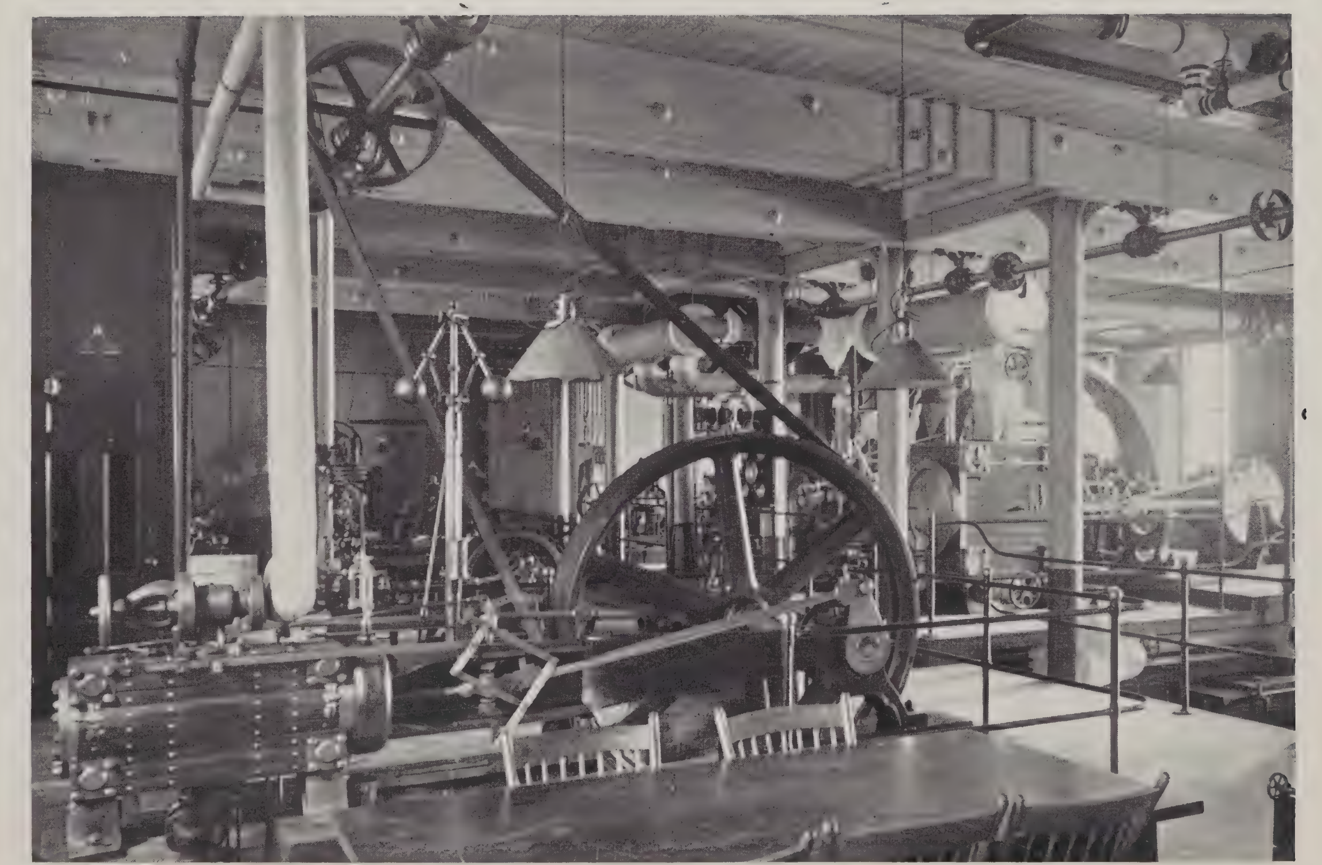
[1] Students who have not had the equivalent of the third year electrical work in Course VI., but have had an amount of Electrical Engineering corresponding to that required in Course II., should confer with Professor Clifford as to preparation to be made during the summer for this course.

[2] References to be studied prior to admission to this course will be furnished by Professor Laws to those who have not had the first part of course 685 in the third year or its equivalent.

[3] Special Course offered to two or more applicants.



PORTION OF HYDRAULIC LABORATORY.



PORTION OF THE STEAM LABORATORY. (ENGINEERING BUILDING A.)

THE ENGINEERING LABORATORIES.

In the Engineering Laboratories the objects sought are the following: first, to give the students practice in such experimental work as engineers, in the pursuit of their profession, are called upon to perform; second, to afford some experience in carrying on original investigations in engineering subjects, with such care and accuracy as to render the results of real value to the engineering community; third, by publishing from time to time the results of such investigations, to add gradually to the common stock of knowledge.

These laboratories are situated in the building on Trinity Place, where they occupy a floor-space of about 23,500 square feet.

The laboratory for testing the Strength of Materials is furnished with the following apparatus: three testing-machines of one hundred thousand pounds capacity and another of fifty thousand pounds capacity for determining tensile strength, elasticity, and compressive strength; a testing-machine of one hundred thousand pounds capacity for determining the transverse strength and stiffness of beams up to twenty-five feet in length, of framing-joints used in practice, and of other structures subjected to a transverse load; a testing-machine of eighteen thousand pounds capacity for determining the transverse strength and stiffness of beams up to fourteen feet in length; apparatus of thirty thousand pounds capacity for making time tests of full-size timber beams; a kiln for drying lumber; apparatus for testing the strength of full-size masonry arches; a machine for testing the torsional strength and stiffness of shafting up to three inches in diameter and to twenty-one feet in length; a torsion machine of sixty thousand inch-pounds capacity; a small torsion machine of six thousand inch-pounds capacity for very delicate work; machinery for the measurement of the twist of shafting; for testing the tensile strength of mortars and cements, and of ropes; a chain testing-machine of 150,000 pounds capacity for testing the effect of repeated stresses upon the elasticity and strength of iron and steel; for determining the strength and elasticity of wire; for determining the strength and elasticity of cloth; for testing the strength of pipe and pipe fittings under hydraulic pressure; and, also, accessory apparatus for measuring stretch, deflection, and twist. Besides the above-stated apparatus, a horizontal Emery testing-machine of three hundred thousand pounds capacity forms a part of the equipment of this laboratory. This machine contains all the essential features of the eight hundred thousand pounds testing-machine built by Lieutenant Albert H. Emery at the Watertown arsenal, and is suitable for testing a compression specimen eighteen feet long, and a tension specimen twelve feet long.

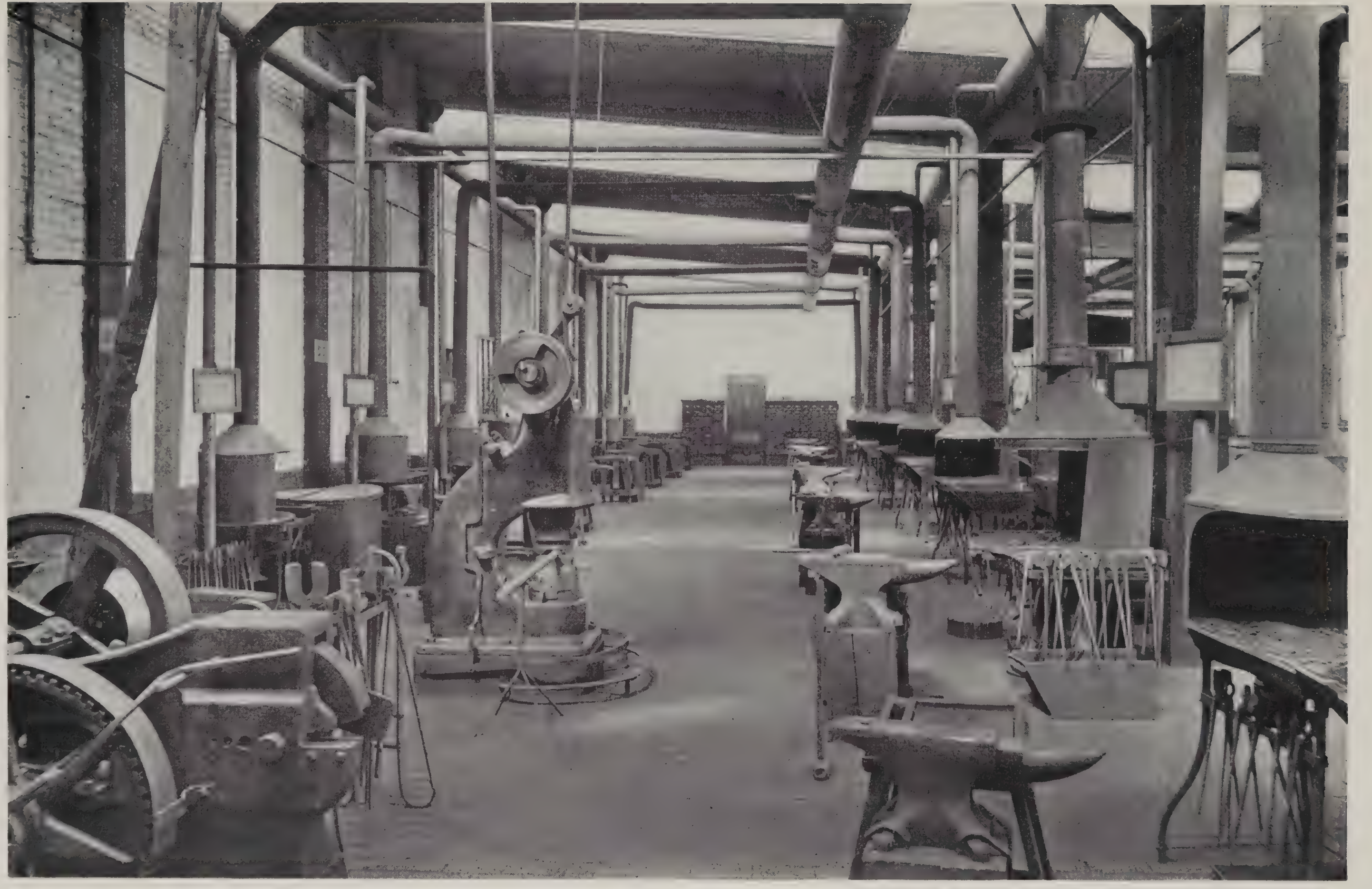
The Hydraulic Laboratory contains a closed steel tank, five feet in diameter and over twenty-seven feet high, arranged for the insertion of orifices, mouthpieces, and other special pieces of apparatus, with gates for controlling the discharge and with connections for supplying water in experiments upon pipes and motors. This tank is connected with a ten-inch standpipe over seventy feet high, so arranged that a constant head may be maintained at any desired level. Two steel tanks, each of about two hundred and eighty cubic feet capacity, give opportunity for the accurate measurement of larger quantities of water than can be weighed directly during experiments. A system of pipes connected both with the main tank and with the pumps is arranged for the insertion of diaphragms, branches, and other apparatus for studying loss of head and the laws of discharge. An attachment has been fitted to the main tank, containing a Pitot tube for studying the laws of velocity in jets, and adjustable points for accurate measurement of the cross-section of jets.

The laboratory is further equipped with a forty-eight-inch Pelton wheel, of thirty horse-power; a three-foot American impulse wheel; a Venturi meter; an eight-inch, a twelve-inch, and two forty-eight-inch weirs, and an orifice tank for measuring water; a centrifugal pump; a rotary pump; two plunger pumps; two pulsometers, one of two-and-one-half-inch discharge pipe and one of five-inch discharge pipe; four three-inch water meters and others of smaller size; and a variety of mercury gauges, standard orifices, mouthpieces, diaphragms, branches, nozzles, etc., for experiments with flowing water under all conditions. A six-inch turbine is arranged to be run under various conditions of head and gate opening in tests for efficiency. There are also two hydraulic rams, one with a two and one-half-inch drive-pipe and the other with a four-inch drive-pipe. The laboratory also contains a steel weir-box, the weir having a standard crest adjustable as to length from zero to five feet, and a seconds pendulum, with chronograph for exact determination of time in experimental work. Water is directly supplied for experiment by the various pumps. The laboratory is also supplied with apparatus by which the suitability of various materials for the construction of roads of pavements may be ascertained.

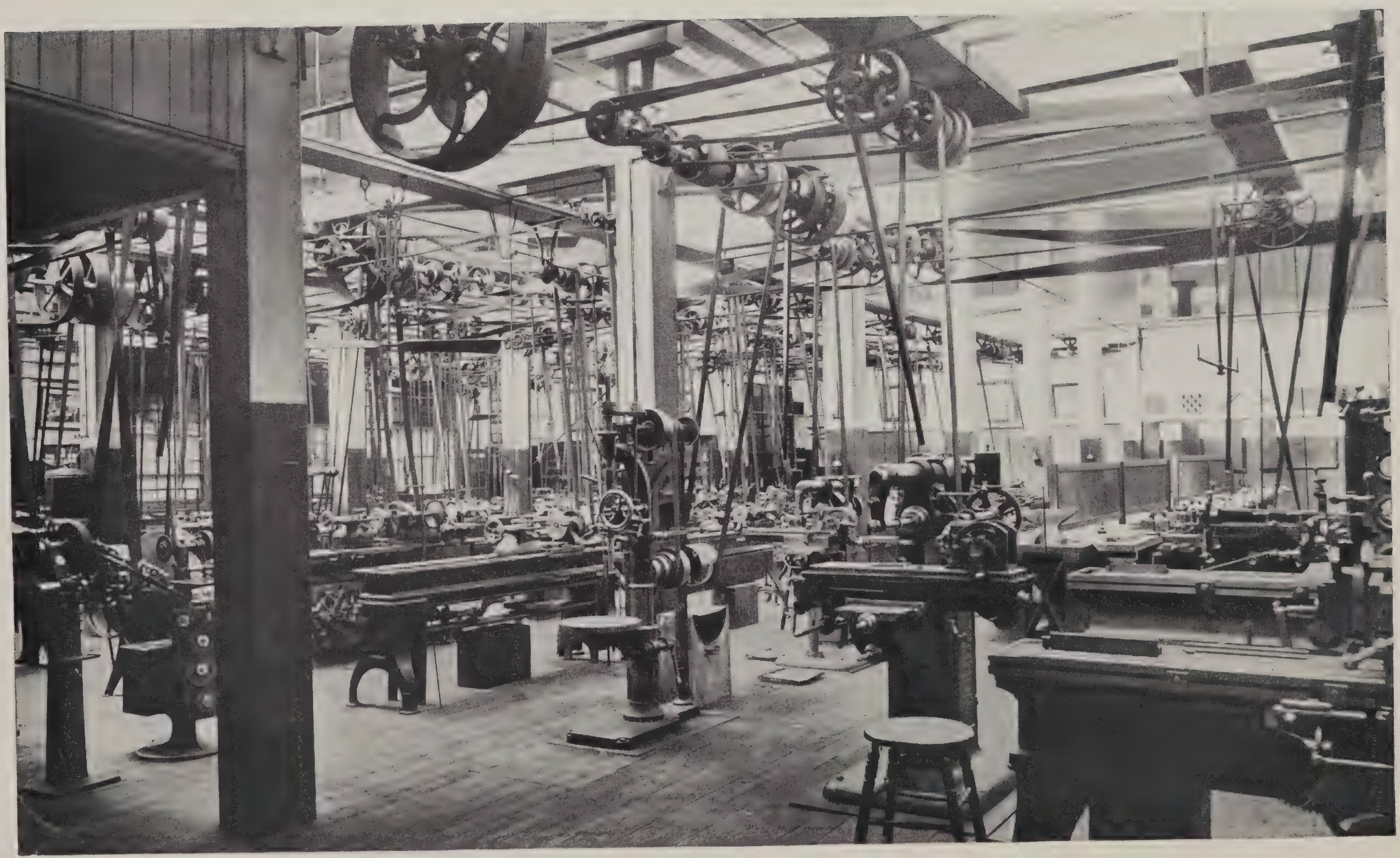
The Steam Laboratory contains a triple expansion engine, with cylinders of nine inches, sixteen inches, and twenty-four inches diameter respectively, and thirty inches stroke, arranged in such a way as to be run single, compound, or triple, as desired for purposes of experiment. This engine is of the Corliss type, and has capacity of about one hundred and fifty horse-power when running triple, with an initial pressure of one hundred and fifty pounds in the high-pressure cylinder. It is connected with a surface condenser and the other apparatus necessary to adapt it to the purposes of accurate experiment. A tandem compound high-speed engine of about two hundred and twenty-five horse-power, having cylinders eleven and nineteen inches in diameter by fifteen inches stroke, is similarly provided with a surface condenser, air pump, and other apparatus needed for testing. This engine transmits its power through a rope drive.

This laboratory also contains a three-stage air compressor adapted to compress one hundred cubic feet of free air per minute to twenty-five hundred pounds pressure per square inch, connected with storage tubes of about fifty-eight cubic feet capacity, and apparatus for accurately determining the weight of air flowing through orifices up to two inches in diameter and at pressures under three hundred and fifty pounds per square inch; a plant for making liquid air; a sixteen horse-power engine, an eight horse-power engine, and a piston valve engine of ten horse-power used for giving instruction in valve setting, etc., and also a thirty-six horse-power gas-engine, a small gas-engine, and a De Laval steam-turbine of seven and one-half horse-power. It is equipped with several surface condensers, a dry air-pump, steam-pumps, injectors and ejectors, calorimeters, mercurial pressure and vacuum columns; apparatus for determining the quantity of steam or air issuing from a given orifice or through a short tube under a given difference of pressure, apparatus for testing steam-engine indicators; apparatus for testing injectors; and indicators, planimeters, gauges, thermometers, anemometers, and other accessory apparatus.

The Engineering Laboratories are provided with a number of friction brakes; with machinery for determining the tension required in a belt or rope to enable it to carry a given power, at a given speed, with no more than a given amount of slip; with four transmission dynamometers; with two machines for determining the coefficient of friction of lubricating oils; with a pendulum and a fly-wheel governor arranged for experimental purposes; with a complete set of Westinghouse air-brake apparatus, including the parts belonging to the cars and to the locomotive, for a twenty-six car train; and with a complete brake outfit for an electric car with the pump and engineer's valve of the New York air-brake; with a locomotive link model; with two hot-air engines; and with cotton machinery as follows: two cards, a drawing-frame, a speeder, a fly-frame, a ring spinning-frame, and a mule, as well as accessory apparatus. There is also an independently fixed superheater capable of superheating ten thousand pounds of steam per hour 250° F. at a pressure of two hundred and fifty pounds. It is connected so that superheated steam may be supplied to the laboratory



HALF OF FORGING LABORATORY.



PORTION OF MACHINE-TOOL LABORATORY.

for various experiments on and with superheated steam. The superheater is so connected to the boilers that efficiency tests can be made upon it. A Westinghouse Parsons steam-turbine of 500 kilowatt capacity has been installed in the laboratory, and is used for making tests and investigations. There are available for purposes of experiment in connection with the work of these laboratories three horizontal tubular boilers in a boiler-house near the Engineering Building with a wrought-iron stack, three feet in diameter and one hundred feet high, fitted with the apparatus necessary to make experiments on the draft of chimneys; two large sectional boilers, situated in the Rogers Building, with a masonry stack three feet square and one hundred feet high; two high pressure (250 pounds) boilers, each of two hundred and fifty horse-power capacity, in the Power Plant of the Institute; a steel stack four feet in diameter and one hundred feet in height, as well as the engines and cooling tower in the Electrical Engineering Laboratory; and a one hundred horse-power boiler, a forty horse-power engine, a number of looms, and other apparatus, in the Mechanical Laboratories on Garrison Street.

A plan of the Engineering Laboratories is appended as they are equipped at the beginning of the school year 1908–09.

MECHANIC ARTS.

Practical instruction in the nature of the materials of construction and in the typical operations involved in the arts is considered a very valuable adjunct to the theoretical treatment of professional subjects. Mechanical Laboratories have been provided, with the more important hand and machine tools, so that the student may acquire a direct knowledge of the nature of metals and woods, some manual skill in the use of tools, and a thorough knowledge of what can be accomplished with them. The Laboratories are located on Garrison Street, and are equipped as described below.

The Carpentry, Wood-turning, and Pattern-making Laboratories contain forty carpenter's benches, two circular-saw benches, a swing-saw, a band-saw, two jig-saws, a buzz-planer, thirty-five wood-lathes, a large pattern-maker's lathe, and thirty-five pattern-maker's benches. The Founding Laboratory contains a cupola furnace for melting iron, two brass furnaces, a core oven, and thirty-two moulder's benches. The Forging Laboratory contains a power-hammer, thirty-three forges, seven blacksmith's vises, one blacksmith's hand-drill, and a power-shear. The Machine-tool Laboratory contains thirty-one engine-lathes and fifteen hand-lathes of approved patterns, a twenty-four-inch turret lathe, three machine-drills, two centering-machines, four planers, a shaping-machine, two universal milling-machines furnished with spiral and gear-cutting attachments, a plain milling-machine, two universal grinding-machines, a cutter and reamer grinder, a twist-drill grinder, two tool grinders, a twenty-four-inch standard measuring-machine, special apparatus for hardening and tempering, and a fully equipped tool-room. The Filing Laboratory contains thirty-two vise benches arranged for instruction in vise work and a tool grinder.

The present pamphlet, while complete in itself, is especially designed to supplement and extend the statement regarding the Course in Mechanical Engineering which is given in the Annual Catalogue of the Institute. The Catalogue also should be read by one purposing to enter this Course. It may be obtained by addressing the Secretary of the Faculty, Professor Allyne L. Merrill.

TITLES OF THESES.

CLASS OF 1902.

The Heating and Ventilation of the Masonic Temple.—C. M. Allen, W. H. Towne.

A Determination of the Friction of the Chapman Double Ball Bearing.—H. A. Ames, J. J. Eames.

A Study and Design of Steam Meters.—C. B. Annett.

Progressive Speed-trial of the Steam Yacht "Helena."—A. L. Appleton.

A Design of an Experimental Yarn Tester.—J. W. Ballard.

A Comparative Fuel Test on a Boiler Plant, including an Investigation of the Action of a Disc Water Meter under Running Conditions.—N. E. Borden, M. Brodie.

The Effect of Heating, Quenching in Oil, and Subsequent Annealing, on the Physical Properties and Microstructures of Steel Castings.—F. Bradley, R. L. Frost.

An Efficiency Test of a Three Hundred Horse-power De Laval Steam Turbine.—H. B. Canby, H. Y. Curry.

Experiments on an Oil Testing Machine.—A. L. Collier.

Tests to determine the Feasibility of using a Bundy Return Steam Trap as a Meter for Condensed Steam.—E. H. Cutter, E. W. Sturtevant.

Experimental Tests on an Automobile Boiler and Gasolene Burner.—W. S. Fitch, C. D. Starr.

Tests on a Nine and One-half Inch Westinghouse Air Pump.—J. M. Fitzgerald.

Design of a Heating and Ventilating System for the Cambridge Latin School.—F. B. Galaher, J. R. Marvin.

Tests on a Pulsometer Steam Pump.—H. N. Hunt.

Tests on the Heating Surface and Boilers of a Large Greenhouse.—J. A. Hutchinson.

Tests on Steel Rivets.—J. D. Ireland.

An Investigation of the Use of the Pitot Tube and an Orifice to measure the Velocity of Air in Tubes at Low Pressures.—C. W. Kellogg, Jr., A. E. Ritchie.

The Velocity of Steam through the Ports of a Stationary Engine.—F. G. Lane, K. Lockett.

The Design of a Heating and Ventilating System for the Springfield High School.—J. J. Mahar, A. H. Nickerson.

A Series of Tests on Heating Cars by Steam from the Locomotive.—H. S. May.

An Investigation of the Economic Disposal of Town Refuse and the Design of a Boiler to utilize the Waste Heat.—R. Mayo, Jr.

Tests on the Strength of Tarred American Hemp Rope, including Tests on the Comparative Strengths of the Most Common Knots.—E. P. Pitts.

The Efficiency of Chain Drives.—C. R. Place, W. H. Sears.

The Arrangement of a Marble Working Plant, and the Design of One of the Saw Mills.—E. T. Pollard.

The Measurement of Air by an Orifice.—F. A. Robbins, Jr.

A Method of Testing a Pneumatic Chipping Hammer.—G. M. Spear.

Calculations on Train Resistance.—H. W. Stebbins, C. C. Stover.

Tests on Spruce Headers.—H. W. Westcott.

Some Tests on a Three-stage Norwalk Air-compressor.—W. L. Wetmore, T. H. Taft.

Tests of a Pneumatic Boring Machine.—O. C. Thanisch.

The Transmission of Heat in a Feed Water Heater.—H. O. Trowbridge.

A Comparative Road Test of Locomotives.—W. H. Williston, P. Weeks.

A Determination of the Distribution of Power in Towing.—L. E. Williams.

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A Study of the Effect of Water and of Oil Hardening on Machinery Steel.—L. W. Adams, J. W. Aylsworth.

Tests on Re-enforced Concrete.—W. H. Adams, I. F. Atwood.

An Investigation of a Vapor Engine.—C. S. Aldrich, E. J. Ruxton.

Experiments on Steel Rivets.—J. F. Ancona.

A Twenty-four Hour Duty-test on a Ten Million Gallon Leavitt Pumping Engine at New Bedford.—S. R. Bartlett, P. J. Kearny.

Tests of a Simple and of a Compound Traction Engine.—J. T. Cheney, C. J. McIntosh.

A Duty-test of an Allis-Chalmers Pumping Engine at West Roxbury, Mass.—F. G. Cox, E. W. Pelton.

Tests on a Pulsometer Steam Pump.—W. H. Donovan.

An Investigation of the Stresses in Locomotive Connecting Rods.—H. H. Fales.

A Study of Wind Pressure.—T. V. Fowler, Jr.

An Efficiency Test of an Automobile Transmission Gear.—C. M. Hardenburgh.

Tests of Concrete Columns Re-enforced with Steel Rods.—G. M. Harris, G. B. Wood.

A Determination of the Exhaust Waste from a Thirty-six Horse-power Ottos Internal Combustion Engine.—J. S. Joseph, R. H. Nutter.

Tests on a Dynamometer for a Steam Motor Carriage.—B. W. Latham, V. M. Palmer.

A Comparative Test of Ventilating Fans.—G. M. McDonald.

A Test of a De Laval Steam Turbine.—J. A. McKenna, J. W. Regan.

A Study of the Line of Resistance on a Concrete Arch.—H. A. Pemberton, S. C. Merrick.

A Design for a Mechanical Pulp Mill.—H. E. Raymond.

An Investigation of the "Economy" Car Heating System.—I. Williams, W. C. Rott.

A Study of the Velocity of Steam through Different Valve Ports.—T. E. Sears.

A Test on a Parsons Steam Turbine at Hartford, Conn.—G. B. Seyms, E. C. Thompson.

Tests on the Prevention of Water on the Train Line,—J. S. Sheafe.

The Effect of Piping upon Indicator Cards as Determined from a Locomotive Road-test.—G. W. Swett.

Tests on a Hydraulic Elevator, and on Elevator-table Connections.—D. Wemyss.

CLASS OF 1904.

An Investigation of the Location of the Line of Resistance of a Concrete Arch.—P. M. Arnold, W. A. Evans.

Moisture Experiments on Train Line.—C. F. Barrett, A. M. Holcombe.

Re-enforced Concrete Beams.—H. O. Blatt, J. D. McQuaid.

Design of a Machine to test the Capacity of Different Materials to resist the Repeated Impact due to a Transverse Blow; also some Tests made on Mild Steel.—S. L. Bradley, C. C. Easterbrooks.

An Investigation of Oil Separators.—F. J. Carty, M. W. Carty.

An Investigation of the Specific Heat of Superheated Steam.—H. H. Cerf, C. King.

Test of an Oil Machine.—W. D. Chandler, A. S. Courtney.

An Investigation of the Variation in the Coefficient of Friction under Varying Conditions.—E. L. Clifford, J. L. Hecht.

An Investigation of a One and Two Foot Submerged Weir.—W. L. Cronin, E. R. Humphreys.

An Investigation of the Efficiency of the Stanley Automobile Engine and Boiler with Special Reference to the Use of Superheated Steam.—J. W. Crowell.

A Road-test on a Compound Locomotive.—M. W. Dole, A. W. Munster.

Tests on Concrete Columns Re-enforced with Steel Rods.—W. L. Doten, C. Y. Ferris.

Comparative Tests on Bearing Metals.—W. H. Edgecombe.

An Investigation of the Flow of Air through Certain Orifices.—E. O. Hiller, A. F. Holmes.

Power Investigations on Cap Spinning Frames.—R. O. Ingram.

An Experimental Study of the Properties of Steel Rivets.—J. A. Keenan.

Tests on Air Filters.—G. E. Libbey, J. L. Lyon.

The Efficiency of the Rife Hydraulic Ram.—E. H. Metcalf.

A Determination of the Distribution of Heat in a Thirty-six Horse-power Otto Gas Engine.—A. W. O'Connor, F. M. Pierce.

Test on a Battery of Twelve "Manning Boilers" at the Amoskeag Manufacturing Company's Plant at Manchester, N.H.—L. Phillips, C. R. Sheafe.

Train Resistance.—W. F. Rech.

Tests of a Wainwright Surface Condenser.—E. F. Rockwood.

An Investigation of Water Hammer in the Drive Pipe of a Rife Hydraulic Ram.—H. T. ROLLINS.

Investigation of an Air-cooled Gasolene Automobile Engine.—E. L. RUFF.

Test on Three Thousand Horse-power Mill Engine at Manchester, N.H.—H. E. THOMPSON, E. P. TRIPP.

A Study of the Coefficient of Friction in the American Compound Ball-bearing and the Design of Suitable Apparatus for the Investigation.—W. D. W. VOSBURY.

An Investigation of the Stresses in Locomotive Connecting Rods with Tests on Full-sized Specimens.—R. A. WENTWORTH.

Plant Test for the Locomobile Company of America, Bridgeport, Conn.—E. J. WILSON, E. T. WOOD.

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Air Filtration with a Coke Filter.—J. C. BAKER, L. CLOUGH.

The Determination of the Heat Necessary to prevent Freezing on Metallic Surfaces Alternately Exposed to Air and Water and of the Best Method of Applying the Same.—A. F. BELDING, A. E. FREEMAN.

A Test of a Gas Engine and a Producer Plant.—W. P. BIXBY, A. M. DEAN.

An Investigation of the Line of Resistance in a Concrete Arch.—C. E. BROAD, P. W. GOLDTHWAITE.

A Test of a Five Hundred Kilowatt Curtis Turbine.—J. H. BROWN, JR., C. R. PRICHARD.

A Test of a Power Plant under Running Conditions.—L. T. BUSHNELL, R. K. CLARK.

The Flow of Air through an Orifice against a Back Pressure.—S. L. COLE, R. C. CUTTING.

A Test on a Five Hundred Kilowatt Curtis Turbine.—E. B. COOPER, P. G. DARLING.

An Investigation of the Heating and Ventilating System at the Fitchburg High School.—I. H. COWDREY.

Tests on an Eight-inch Three-stage Worthington Turbine Pump.—W. G. EICHLER, H. L. R. WALKER.

A Thermodynamic Study of an SO^2 Waste Heat Engine as Applied to a Thirty-six Horse Power Otto Gas Engine.—J. H. FLYNN, JR., J. W. TAYLOR.

An Investigation of the Specific Heat of Superheated Steam.—C. E. GAGE, R. W. MORSE.

An Investigation of the Effect of Burnt Products on the Explosive Power of Gas and Air.—A. P. GERRY.

An Investigation of the Flow of Superheated Steam through an Orifice.—W. C. GILMAN, A. L. WHITMARSH.

An Experiment to show the Effect of Impact on Mild Steel.—C. H. GRAESSER.

The Investigation of a Pneumatic Motion for a Braiding Machine.—P. G. HILL.

An Apparatus for Measuring the Deflection of Locomobile Driver Springs.—P. E. Hinckley.

The Slip and Creep of Belting.—J. H. Holliday, Jr.

Stresses in Locomotive Connecting Rods with Tests on Full-sized Specimens.—W. G. Housekeeper.

Tests on the Ventilating Apparatus of the East Boston Tunnel.—E. J. Hurley.

An Investigation of the Pneumatic Tube Mail Service.—G. B. Jones, M. B. Landers.

A Test of Reinforced Concrete Beams.—C. D. Klahr, J. M. Lambie.

An Investigation of Water Hammer.—H. W. Lackman.

Tests of a Boyer Cooling Tower at the Malden Electric Company.—N. Lombard.

Tests on a Napier Automobile Engine.—E. H. Lorenz, J. B. Whitmore.

Tests on Concrete Columns Reinforced with Steel Rods.—J. S. Loughlin, J. E. Lynch.

The Determination and Elimination of Moisture in the Air-brake Train-pipe.—W. N. MacBriar.

Torsional Tests on Spring Steel.—H. J. MacIntire.

Comparative Tests on Water Tube Boiler Tube Cleaners.—R. W. McLean.

A Test of a De Laval Steam Turbine Pump at the Massachusetts Institute of Technology.—G. D. Marcy, A. G. Prescott.

A Test on the American Superheater.—L. M. Pease.

Tests on a Wainwright Even Flow Condenser.—F. A. Pirie, J. A. Pitts.

Economy Tests of a Fourteen and One-half Inch by Sixteen Inch Hornsby-Akroyd Oil Engine.—G. W. Prentiss, F. E. Payne (XIII.).

A Study of a Cooling Tower with Tests on the Worthington Cooling Tower at the Massachusetts Institute of Technology.—C. L. Rodgers.

Pressure and Temperature Variation along a De Laval Steam Turbine Nozzle.—C. E. Smart, H. J. Stevenson.

A Design of an Electric Drive for Sewing Machines.—G. C. Thomas.

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The Design and Testing of a Metering Device to measure Continuously the Feed Water used by a Large Battery of Boilers.—Daniel Adams.

An Experimental Investigation of the Specific Heat of Superheated Steam.—J. W. Anderson, H. S. Philbrick.

A Plant Test on the Power Plant of the Blackstone Manufacturing Company at Blackstone.—H. J. Ball, H. W. Brown.

A Duty-test of a Barr Pumping Engine.—F. H. Bentley, R. E. Cushman.

A Series of Tests on a Condenser's Circulating Pump with Varying Vacua in the Discharge Pipe.—A. S. Boynton, C. J. Rich.

A Record of Tests made on the Institute Boilers to determine the Comparative Costs of Using Hard and Soft Coal.—C. R. Burleigh, W. W. Gaylord.

Somes Tests on One to Three Mortars, showing the Effect of Varying Amounts of Water and Relative Strengths of Mortars with Different Sands.—C. H. Chase, W. I. Lourie.

An Investigation of the Effect of Mixing Water upon the Strength of Cement and Cement Mortar Briquettes.—A. M. CHENEY.

An Efficiency Test on a Westinghouse Gasolene Engine at a Country House.—W. B. CLIFFORD, G. M. WINNE.

A Determination of the Live Load on Locomotive Driving Springs under Actual Running Conditions.—H. V. O. COES, C. A. HOWARD.

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A Test of a Pumping Plant at Lake Assawampset.—T. W. FABER, H. T. GAMMONS.

Tests to determine the Minimum Velocity of Steam Necessary to prevent Downflow of Condensation through Vertical Pipes.—R. D. FARRINGTON, H. H. NELSON, Jr.

Tests on a One Thousand Kilowatt Westinghouse-Parsons Steam Turbine at Haverhill.—E. D. A. FRANK, H. C. HENRICI.

Test on a Deisel Engine at the Baldwin Locomotive Works.—F. M. FULLER, E. M. SMITH.

An Investigation of Air Brakes.—J. N. GLADDING.

A Test to determine the Economy and Thermal Efficiency of a Steam Generating Plant using Crude Oil Fuel.—P. K. GRIFFIN.

Tests on a Fifteen Hundred Kilowatt Westinghouse-Parsons Steam Turbine.—W. A. HARDY, P. J. KENNEDY.

An Investigation of a Hydro-electric Plant.—C. W. HAWKES, R. S. CLARKE.

An Investigation of the Heating and Ventilating of the American Waltham Watch Factory.—R. R. HEUTER.

Tests on a Five Hundred Kilowatt Westinghouse-Parsons Turbine at the Savannah Electric Company, Savannah, Ga.—H. O. C. ISENBERG, J. LAGE.

Tests on Two Water Turbines at the Chittenden Power Company, Rutland, Vt.—J. W. JOHNSON, H. A. LIGHT.

Tests on Boilers employing Natural and Forced Draft.—K. F. JUENGLING, P. S. SCHMIDT.

A Commercial Test of a Five Thousand Kilowatt Curtis Turbine, Waterside Station, New York Edison Company.—W. J. KNAPP, L. A. RILEY.

An Investigation of the Stresses in Locomotive Connecting Rods with Tests on Full-sized Specimens.—C. A. MERRIAM.

The Design of an Electrically Driven Fine Goods Cotton Mill.—C. W. MOWRY.

A Test on an Induced Draft System at the Merrimac Manufacturing Company's Plant at Lowell.—J. R. O'HARA, A. T. THOMAS.

A Series of Tests on a Fifteen Horse-power, Two-cycle Hudson Gas Engine.—R. W. SEYMS, D. A. STEWART.

A Study of the Coefficient of Friction of Ball and Roller Bearings.—P. B. Stanley.

Experiments on the Flow of Steam through Orifices under Small Differences of Pressure.—A. C. Taylor.

A Report of a Test of the Pumping Station of the Wellesley Water Works.—DeWitt M. Taylor, T. C. Webber.

A Design of an Experimental Yarn Testing Machine.—W. P. Terrell.

Test of a Five Hundred Kilowatt Turbine.—W. H. Trask, Jr.

A Study of the Heating and Ventilation of the Imperial Diet Building at Berlin, Germany.—L. H. Tripp, E. L. Wilson.

A Test of a Napier Gasolene Automobile Engine.—A. T. Trowbridge, G. C. Young.

A Test on a Twelve Horse-power True Gas Engine and Suction Gas Producer. Louis Tuckerman.

Some Efficiency Tests on a Blackmer Rotary Pump.—W. C. Turner.

The Electrical Resistance Furnace.—C. E. Warren.

A Test on the Suction Gas Producer Plant of W. F. Schrafft & Sons, Boston.—J. L. Wick, Jr.

Distribution of Strains in Reinforced Concrete Beams.—J. R. Williams.

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A Test on an Air Brake Rack.—J. M. Baker.

A Determination of the Pressure Temperature Diagram of the Saturated Vapor of Completely Denatured Alcohol.—E. M. Berliner.

An Investigation of the Thomas Calorimeter.—W. W. Bigelow, J. W. Hanford.

Investigation of Locomotive Driving Springs.—E. D. Boles, E. B. Snow.

A Determination of the "Slip" plus "Creep" in a Three Hundred and Fifty Horse-power Rope Drive.—C. A. Bowen, A. R. Jealous.

The Design of a Heating and Ventilating System for a High School Building. L. H. Cutten.

Thesis on Fan Performance.—C. R. Denmark, J. T. Mahar.

Tests of a Cast Iron Indirect Radiator.—V. H. Dickson, J. S. Nicholl.

The Effect of Freezing and Absorption of Water on Fire Bricks.—E. C. Evans.

Stationary Tests of a White Steam Automobile.—O. G. Fales, G. R. Norton.

An Investigation of Air Brakes.—J. H. Fellows.

Investigation of a Gas Producer.—L. A. Freedman, L. Wetmore.

Test of Seventy-two Million Gallon Pumping Engine of Boston (Main Drainage Pumping Station).—E. F. Kelly, R. H. Kudlich.

An Investigation of the Effect of Different Percentages of Water and Cement in Plum Island Sand Mortars.—R. E. Keyes, J. T. Lawton.

Thesis on a "True" Gas Engine and Gas Producer.—H. A. Kingsbury, M. H. Eisenhart.

A Design for a One Thousand Horse-power Producer Gas Power Plant.—A. G. Labbé, A. B. Arnold.

Speed Losses in Successive Counter Shaft Drives.—B. P. Luce, W. S. Lucey.

Coefficient of Flow for Narrow Weirs with High Heads; Full Contraction.—A. P. Mathesius.

Test on Taylor Gas Producers as used by the Boston Elevated Railway Company.—N. A. Middleton.

An Investigation of the System of Heating and Ventilation installed in the New Christian Science Temple.—A. Miller, D. W. C. Ruff.

An Investigation and Comparison of Different Methods of Vacuum Air Cleaning as applied to Carpets.—S. R. Miller.

Test of the Gas Engine Power Plant of the Boston Elevated Railway Company.—K. Moller, D. G. Robbins.

Test on the Power Plant of the Suburban Manufacturing Company at Waltham, Mass.—B. Nichols, H. H. McChesney, E. H. Packard, A. Macomber.

Tests on Cutting Wrought Iron on a Metal Saw Cutting-off Machine.—C. W. Nutter.

Peat Fuel: its Production and Value as Determined by a Boiler Test.—A. Pope.

A Comparative Road Test of a Superheating and non-Superheating Locomotive.—M. Rambo, R. E. Thayer.

A Study of the Stresses and Strains in Reinforced Concrete Beams.—J. R. Randall, E. Rich.

An Investigation of the Variation of Angular Velocity in Reciprocating Engines.—E. C. Richardson, P. V. Dodge.

Radiation Efficiencies of Air Cooled Gas Engine Cylinders.—F. Ripley, Jr., E. H. Squire.

The Design of a Testing Machine for Subjecting Riveted Joints to Repeated Stress.—S. E. Rockwell, P. B. Webber.

Wind Pressure on Curved Surfaces.—G. Small, W. F. Turnbull.

The Effect of Superheated Steam on Cast Iron.—H. A. Terrell.

Tests on the Transverse Strength of Cast Iron.—J. J. Thomas, C. A. Eaton.

Plant Test on Power Plant of Wallingford Manufacturing Company.—H. S. Wilkins.

CLASS OF 1908.

The Effect of Moisture in Air Brake Distributing Valves.—H. E. Allen, G. T. Glover.

An Investigation of Running Balance at High Rotative Speeds on a Hydro-extractor.—R. C. Angell, J. M. Talbot.

Comparative Coal Tests using Forced and Natural Drafts.—R. A. Angus, H. R. Callaway.

Economy Tests of a Two Thousand Kilowatt Curtis Turbine at the Quincy Point Power Station of the Old Colony Street Railway Company.—C. H. Bangs, S. F. Kedy.

A Test on Chrome-tan Belting and an Investigation of the Variation of the Bangs, S. F. Kedy.

A Test on Chrome-tan Belting and an Investigation of the Variation of the Sum of the Tensions.—J. S. Barnes, J. H. Dennedy.

Carburation in Automobiles Engine.—F. K. Belcher, S. H. Daddow.

Tests on a Producer Gas Engine Plant.—H. W. Blackburn, C. A. Edmonds.

Determination of the Coefficient of the Trapezoidal Weir of Cippolette.—F. M. Bond, P. R. Powell.

Investigation of the Flow of Air through a Venturi Meter.—K. C. Boush, I. M. Guilford.

The Efficiency and Losses in a Hydro-electric Power Plant.—G. C. Brooks, A. A. Longley.

A Study for Proper Formulas and Calculations for Reinforced Concrete Beams. P. C. Brown.

Investigation of the Starrett Air Lift Pump.—J. M. Burch, Jr., W. E. Caldwell.

Investigation of the Friction Losses in the Rubber Hose as used with the Vacuum Cleaner.—H. L. Carter, C. N. Cochrane.

Variation of Capacity with Different Heads and Speed of the Centrifugal Pump at the Metropolitan Sewerage Station, East Boston.—B. W. Cary, J. B. Sando.

Efficiency Test of a Five Hundred Kilowatt Curtis Turbine at the United Shoe Machinery Company's Works, Beverly.—L. P. Cassino, C. A. Hall.

Investigation of the Steam Economy of a Woolen Mill.—D. W. Clark, F. J. Friedman.

The Protection of Steam Heated Surfaces against Heat Loss.—L. A. Clark, C. H. Spiehler.

Investigation of the Stiffness of Steam Pipe Bends.—L. Coffin, H. S. Eames.

Friction of the Chapman Double Ball Bearing.—A. S. Cohen.

A Turbine Plant Test at the Amoskeag Mills, Manchester, N.H.—R. C. Collins, B. S. Leslie.

Efficiency Test on a Smoke Consumer.—H. C. Faxon, E. R. Hall.

Efficiency Test on a Producer Plant.—W. D. Ford, M. Sampson.

Tests on Cutting Speed of Lathe Tools.—J. T. Gallagher, H. C. Lord.

Design of a Heating System for the Senate Office Building at Washington, D. C.—B. L. Gimson.

Artificial Humidification and Tests on its Production in Textile Industries.—J. E. Hale.

An Investigation of the Heating and Ventilating Plant of the Harvard University Medical School.—C. E. Hanson.

Determination of the Effects of a Waterproofing Compound on the Bond between Concrete and Steel.—S. F. Hatch, G. C. Lees.

Tests on Denatured Alcohol Fuel in a Two-cycle Engine.—W. R. Heilman.

The Flow of Air in Pipes.— C. L. Hussey, J. W. Wattles.

The Design of a High-speed Braiding Machine.—H. R. Kennison.

Transverse Tests of Driving Spring Leaves.—L. Loeb.

Investigation of the Economy of an Air Compressor Plant.—W. J. Pierce, A. T. Scannell.

An Investigation of the Experiments to Determine the Shearing Strength of Rivet Metal—Double Shear.—H. A. Rapelye.

Increase in Capacity of a Gasoline Automobile Engine without Regard to Efficiency.—J. R. Reyburn.

Investigation of the Stresses in Hooks and Open Links.—C. M. Steese.

An Experimental Investigation of the Strains in Steel Beams.—R. B. Weiler.

Flow of Steam through an Orifice under Small Differences of Pressure.—M. Yendo.

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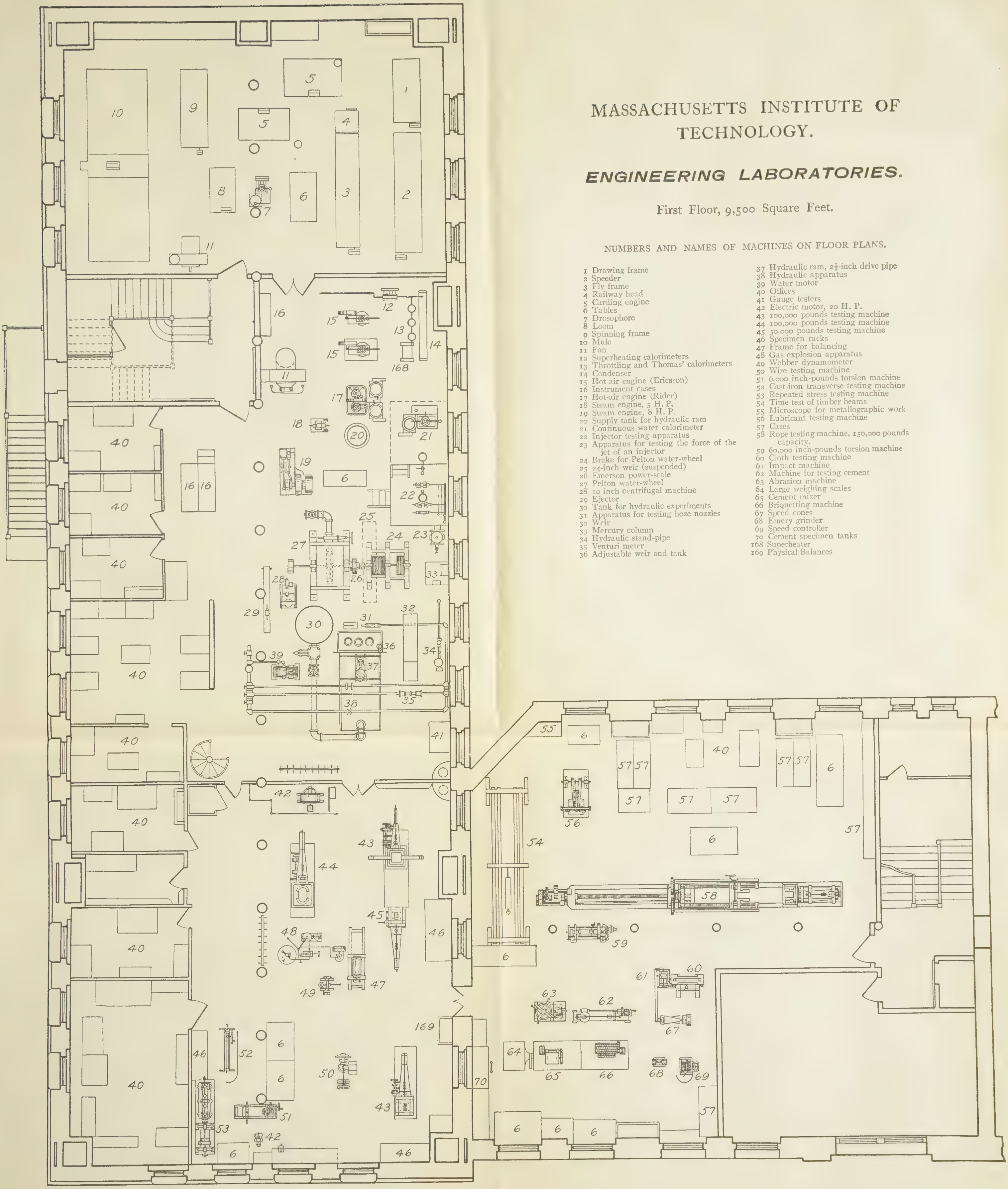

NUMBERS AND NAMES OF MACHINES ON FLOOR PLANS.

1	Drawing frame
2	Speeder
3	Fly frame
4	Railway head
5	Carding engine
6	Tables
7	Drosophore
8	Loom
9	Spinning frame
10	Mule
11	Fan
12	Superheating calorimeters
13	Throttling and Thomas' calorimeters
14	Condenser
15	Hot-air engine (Ericsson)
16	Instrument cases
17	Hot-air engine (Rider)
18	Steam engine, 5 H. P.
19	Steam engine, 8 H. P.
20	Supply tank for hydraulic ram
21	Continuous water calorimeter
22	Injector testing apparatus
23	Apparatus for testing the force of the jet of an injector
24	Brake for Pelton water-wheel
25	24-inch weir (suspended)
26	Emerson power-scale
27	Pelton water-wheel
28	10-inch centrifugal machine
29	Ejector
30	Tank for hydraulic experiments
31	Apparatus for testing hoze nozzles
32	Weir
33	Mercury column
34	Hydraulic stand-pipe
35	Venturi meter
36	Adjustable weir and tank
37	Hydraulic ram, 2½-inch drive pipe
38	Hydraulic apparatus
39	Water motor
40	Offices
41	Gauge testers
42	Electric motor, 20 H. P.
43	100,000 pounds testing machine
44	100,000 pounds testing machine
45	50,000 pounds testing machine
46	Specimen racks
47	Frame for balancing
48	Gas explosion apparatus
49	Webber dynamometer
50	Wire testing machine
51	6,000 inch-pounds torsion machine
52	Cast-iron transverse testing machine
53	Repeated stress testing machine
54	Time test of timber beams
55	Microscope for metallographic work
56	Lubricant testing machine
57	Cases
58	Rope testing machine, 150,000 pounds capacity.
59	60,000 inch-pounds torsion machine
60	Cloth testing machine
61	Impact machine
62	Machine for testing cement
63	Abrasion machine
64	Large weighing scales
65	Cement mixer
66	Briquetting machine
67	Speed cones
68	Emery grinder
69	Speed controller
70	Cement specimen tanks
168	Superheater
169	Physical Balances

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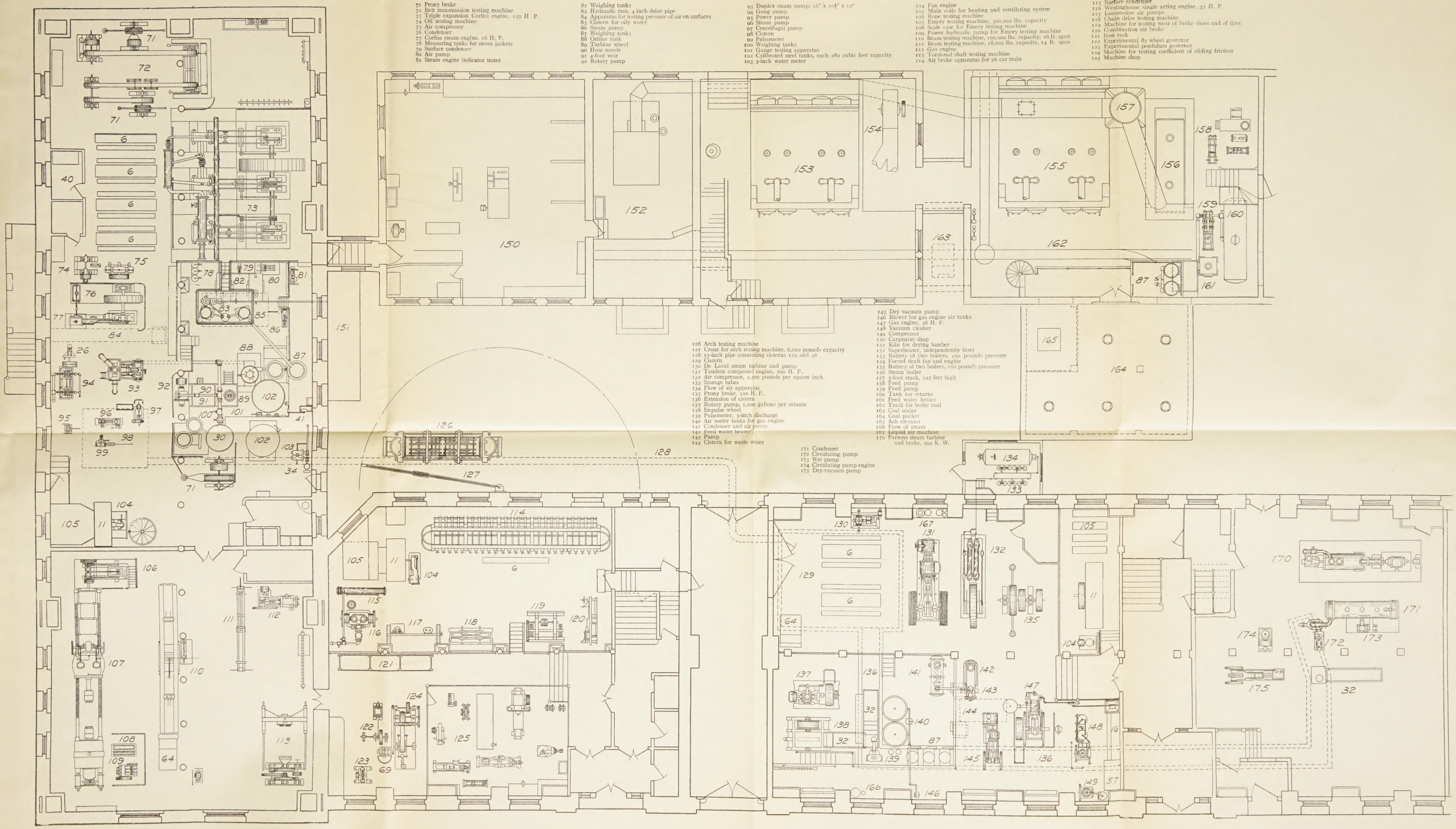
Basement, 18,500 Square Feet.

NUMBERS AND NAMES OF MACHINES ON FLOOR PLANS.

71	Prony brake
72	Belt transmission testing machine
73	Triple expansion Corliss engine, 150 H P.
74	Oil testing machine
75	Air compressor
76	Condenser
77	Corliss steam engine, 16 H. P.
78	Measuring tanks for steam jackets
79	Surface condenser
80	Air pump
81	Steam engine indicator tester
82	Weighing tanks
83	Hydraulic ram, 4-inch drive pipe
84	Apparatus for testing pressure of air on surfaces
85	Cistern for oily water
86	Steam pump
87	Weighing tanks
88	Orifice tank
89	Turbine wheel
90	Hose nozzle
91	4-foot weir
92	Rotary pump
93	Duplex steam pump, 16" x 10½" x 12"
94	Gang pump
95	Power pump
96	Steam pump
97	Centrifugal pump
98	Cistern
99	Pulsometer
100	Weighing tanks
101	Gauge testing apparatus
102	Calibrated steel tanks, each 280 cubic feet capacity
103	3-inch water meter
104	Fan engine
105	Main coils for heating and ventilating system
106	Rope testing machine
107	Emery testing machine, 300,000 lbs. capacity
108	Scale case for Emery testing machine
109	Power hydraulic pump for Emery testing machine
110	Beam testing machine, 100,000 lbs. capacity, 26 ft. span
111	Beam testing machine, 18,000 lbs. capacity, 14 ft. span
112	Gas engine
113	Torsional shaft testing machine
114	Air brake apparatus for 26 car train
115	Surface condenser
116	Westinghouse single acting engine, 35 H. P.
117	Locomotive air pumps
118	Chain drive testing machine
119	Machine for testing wear of brake shoes and of tires
120	Combination air brake
121	Iron rack
122	Experimental fly wheel governor
123	Experimental pendulum governor
124	Machine for testing coefficient of sliding friction
125	Machine shop
126	Arch testing machine
127	Crane for arch testing machine, 6,000 pounds capacity
128	12-inch pipe connecting cisterns 129 and 98
129	Cistern
130	De Laval steam turbine and pump
131	Tandem compound engine, 200 H. P.
132	Air compressor, 2,500 pounds per square inch
133	Storage tubes
134	Flow of air apparatus
135	Prony brake, 100 H. P.
136	Extension of cistern
137	Rotary pump, 1,000 gallons per minute
138	Impulse wheel
139	Pulsometer, 5-inch discharge
140	Air meter tanks for gas engine
141	Condenser and air pump
142	Feed water heater
143	Pump
144	Cistern for waste water
145	Dry vacuum pump
146	Blower for gas engine air tanks
147	Gas engine, 36 H. P.
148	Vacuum cleaner
149	Compressor
150	Carpenter shop
151	Kiln for drying lumber
152	Superheater, independently fired
153	Battery of two boilers, 250 pounds pressure
154	Forced draft fan and engine
155	Battery of two boilers, 250 pounds pressure
156	Steam boiler
157	5-foot stack, 125 feet high
158	Feed pump
159	Feed pump
160	Tank for returns
161	Feed water heater
162	Track for boiler coal
163	Coal scales
164	Coal pocket
165	Ash elevator
166	Flow of steam
167	Liquid air machine
170	Parsons steam turbine and brake, 500 K. W.
171	Condenser
172	Circulating pump
173	Wet pump
174	Circulating pump engine
175	Dry-vacuum pump



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